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Three new blindsnakes (Squamata: Typhlopidae) from northwestern Australia

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Abstract - Three new species of Ramphotyphlops are described from localities in northwestern Western Australia. Two are represented by a single specimen only, the third by four specimens. Each of the new species differs markedly from all previously described members of the genus. The discovery of these new species highlights the very incomplete state of knowledge of the fossorial herpetofauna of northwestern Australia, in particular the Typhlopidae.

INTRODUCTION
The recent description of new species of blindsnakes from Western Australian (Aplin and Donnellan 1990), Queensland (Ingram and Covacevich 1994) and the Northern Territory (Shea and Horner 1997) has drawn attention to the very incomplete knowledge of Australian Typhlopidae, in particular those of northern Australia. In this paper I describe three additional species of typhlopids from localities in the northwest region (see Figure 1), each based on very distinctive specimens collected over recent years.

The head scale terminology and methods of scale counting are as described previously by Aplin and Donnellan (1990), based on those of Waite (1918) and Storr (1981). Vertebral scale counts include the frontal scale and extend back to a point directly opposite the vent. Where such counts are unavailable for certain key species or specimens, I have cited ventral scale counts; these are probably 3-5 higher than the corresponding vertebral scale count in any individual. Subcaudal scale counts were taken between the vent and the tail tip, but not including the terminal spine. Following Shea and Horner (1997), the degree of body elongation is indicated by body width (BW) as a percentage of snout-vent length (SVL). All measurements are given in millimeters (mm).

SYSTEMATICS

Ramphotyphlops splendidus sp. nov.
Figures 2-4

Material Examined

Holotype
R119900 in the Western Australian Museum, an adult female collected on 3 April 1995 by Tom and Nancy Heger at the Ranger's residence, Milyering Well, Cape Range National Park, Western Australia in 22°01'S 113°56'E. Heart and liver frozen in liquid nitrogen and stored in -80°C ultrafreeze at the Western Australian Museum.

Diagnosis

A moderately elongate and stout-bodied Ramphotyphlops with 20 midbody scale rows, moderate number of vertebral scales (377), rostrum angular in profile and weakly trilobate in dorsal view, nasal cleft intersecting second labial and terminating just forward of the nostril, and grey dorsum clearly demarcated from white venter.

Description

A moderately elongate and stout-bodied species (see Figure 2).

SVL 498 mm; tail without spine 11 mm, including spine 13.5 mm. Preserved body 11.3 mm (width) by 12.3 mm (depth) anteriorly, and 10.2 mm by 12.7 mm posteriorly. Body width averages 2.16% of SVL.

Vertebral scales 377, counted from behind frontal to above vent. Subcaudal scales 13, excluding conical spine.

Circumferential scale rows 20 along entire length of body.

In life, dorsal surface of head, body and tail dull-grey, abruptly differentiated from all-white venter along jagged boundary (scales along boundary are unicoloured: all-grey or all-white). On body, number of pigmented scale rows 8-9, remaining 11-12 rows immaculate. On neck, pigmented band reduced to 6-7 rows; 13-14 rows immaculate. Dorsum of head pigmented, terminating just forward of eyes. Subocular region and whole of
snout unpigmented (see Figure 3a-b). Under-surface and tip of tail immaculate.

General form of head and details of scalation illustrated in Figure 3-4. Head moderately attenuate, with snout bluntly angular in profile and weakly trilobed from above. Eyes relatively large, positioned deep to anterodorsal corner of ocular scale. Rostral measures 5.3 mm from tip to posterior margin; maximum width 4.7 mm on upper surface; terminates just forward of line drawn across front of eyes. Leading edge of rostral angular but not sharp-edged. Nasals separated dorsally by narrow contact between rostral and prefrontal. Nasal cleft originates from anterior end of second supralabial, passes through nostril to terminate halfway between nostril and rostral. Nostrils shielded by dorsolateral narial prominences; nostril and nasal cleft not visible from above. Preocular smaller than nasal and ocular, broadly separated from prefrontal by intervening supraocular. Lower border of preocular broadly overlapping supralabials 2–3. Ocular subequal to nasal in overall size, ventral portion wedged between supralabials 3 and 4. Supralabials increase in size posteriorly; supralabial 4 terminates forward of posterior margin of ocular. Prefrontal considerably longer and slightly wider than body scales; deeply wedged between nasal and supraocular on each side. Supraoculcals and parietals larger than frontal which is comparable in size to succeeding vertebral scales.

Microscopic scale organs present but inconspicuous on most head scales; most abundant on ventral and lateral surfaces. Tubular glands inconspicuous owing to lack of contrasting pigment.

Right oviduct elongate but tightly pleated; ovaries with numerous oocytes measuring 3 mm in length. Individual clearly mature and entering active reproductive phase.

Hindgut with short caecum, 23 mm in length, opening into gut 47 mm (39 scale rows) forward of vent.

Etymology
Splendidus (Latin): magnificent!

Comparison with other species
The elongate, stout-bodied form and 20 mid-body scale rows of *R. splendidus* limit meaningful comparisons to only a small number of species. *Ramphotyphlops pinguis* (Waite, 1897) from southwestern Australia has a similar head form and nasal cleft arrangement, but differs from *R. splendidus* in being less elongate (SVL to 491 mm) with lower vertebral scale counts (280–338), and in having a less abrupt transition between the dorsal and ventral colouration and a more extensively pigmented head. *Ramphotyphlops splendidus* also has a slightly larger eye and a slightly more
Three new blindsnakes projecting rostral ‘beak’ than any *R. pinguis* examined. *Ramphotyphlops muretensis* (Gray, 1845) and *R. proximus* (Waite, 1893) of eastern Australia are similar to *R. splendidus* in body proportions, but have a very different arrangement of the nasal cleft (intersects the first labial and extends well past the nostril onto the dorsal surface of head).

**Remarks**

*R. splendidus* is morphologically most similar to *R. pinguis* of southwestern Australia, but with slight differences in head form, meristics and body colouration. However, these represent fairly trivial differences within the broader context of morphological diversity among Australasian typhlopids, and it is likely that the two species are closely related.

The vertebrate fauna of the Cape Range peninsula includes taxa with diverse biogeographic affinities: southern, arid zone and northern (Kendrick 1993). The only currently recognised endemic vertebrate is *Lerista albohirsia* Kendrick, 1989 which is restricted to the dissected limestone country of the Cape Range anticline. However, several additional endemic lizard species (of *Crewatylus* and *Diplodactylus*) await description.

With only a single record of *R. splendidus*, it is clearly premature to comment on habitat preference. The Ranger’s residence at Cape Range National Park is located on the Tantabiddi Terrace, an emergent coral limestone platform of last interglacial age (Wyrwoll et al. 1993). The terrace is mantled by a thin veneer of weakly consolidated sand and supports a degraded coastal complex dominated by *Acacia* spp., *Melaleuca cardiophylla* and/or *Hibbertia specia* over *Triodia* (Keighery and Gibson 1993). In many areas, introduced Buffel Grass, *Cenchrus ciliaris*, has virtually replaced the original ground cover.

The discovery of a large-bodied typhlopid in northwestern Australia runs counter to the general trend in body size within the genus. In general, northern Australian typhlopids are small to medium-sized animals and they are often exceptionally elongate and slender. The few exceptions, such as *R. ligatus* (Peters, 1879) and *R. polygrammicus* (Schlegel, 1839), come from areas of high seasonal humidity such as the Cape York region of Queensland and the Kimberley. In contrast, many typhlopids from southern...
temperate regions are larger and stouter-bodied (e.g., *R. pinguis*, *R. proximus*, *R. nigrescens*). It would be of great interest to investigate the physiological and ecological basis of this trend and to further examine the special case of *R. splendidus*.

*Ramphotyphlops splendidus* rivals *R. pinguis* as the largest typhlopid species recorded in Western Australia. Its discovery on the Cape Range peninsula, in an area visited over the years by many different herpetologists and other naturalists, is noteworthy, and underscores the fact that our knowledge of the terrestrial vertebrate fauna of even the ‘better-known’ parts of Australia remains incomplete.

The apparent scarcity and potentially restricted distribution of *R. splendidus* give cause for concern regarding its future survival. Although largely protected within a national park, the species presumably depends upon certain taxa of ants for food, and these in turn may be sensitive to changes in groundcover ecology associated with the increasing dominance of Buffel Grass. Further information on the distribution and ecology of *R. splendidus* is urgently required.

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**Figure 3** External features of the head of *Ramphotyphlops splendidus* sp. nov., showing basic form and distribution of pigment in relation to scale boundaries and major structural elements in a) dorsal and b) lateral views.

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**Ramphotyphlops longissimus** sp. nov.

**Material Examined**

**Holotype**

RI20049 in the Western Australian Museum, an adult female collected on 22 May 1995 by Mr Lloyd Whitsed at Bandicoot Bay, Barrow Island, Western Australia in 20°54'S 115°22'E. Heart and liver frozen in liquid nitrogen and stored in -80°C ultrafreeze at the Western Australian Museum.

**Diagnosis**

An exceptionally elongate and slender *Ramphotyphlops* with 16 midbody scale rows, extremely high number of vertebral scales (approx. 750), strongly depressed, rectangular-shaped head with inflated and rounded rostrum, nasal cleft intersecting the second labial scale and terminating just forward of the nostril, and head and body almost completely without pigment.

**Description**

An extremely elongate and slender-bodied
Figure 4 Details of cephalic scalation of *Rhamphothelphus splendidus* sp. nov. in a) dorsal, b) lateral views and c) ventral views.
species. SVL 266 mm; tail 2.4 mm including minute spine. Preserved body 1.8 mm (width) by 2.1 mm (depth) anteriorly, and 1.8 mm by 2.3 mm posteriorly. Body width averages 0.83% of SVL.

Vertebral scales approximately 750 (two counts yielded 732, 766; very small size and lack of pigment prohibits more accurate determination). Subcaudal scales 13, excluding minute conical spine.

Circumferential scale rows 16 along entire length of body.

In life, body appeared translucent, without any obvious pigment apart from very small eyes. Under magnification, preserved specimen shows no other pigment in anterior body but very faint reticulation ('ghosting' of dorsal scale margins) posteriorly.

General head form and details of scation illustrated in Figure 5. Head strongly depressed, and rectangular as seen from above. Rostrum inflated and rounded in profile. Eyes small but darkly pigmented, positioned on top of head deep to anterolateral corner of mildly bulging supraocular scales. Rostral ovate as viewed from above, slightly longer than wide; terminates forward of eyes. Nasal inflated, projecting anterolaterally to produce rectangular head form. Nostril large, subequal to eye. Nasal cleft originates from second supralabial, passes above nostril before terminating on nasal, well short of rostral. Nostril and nasal cleft not visible from above. Preocular smaller than nasal, broadly separated from prefrontal by intervening supraocular. Anterior border of preocular intersects upper border of second supralabial, just behind nasal cleft. Lower border overlaps supralabials 2–3. Ocular larger than nasal and preocular, ventral portion wedged between supralabials 3 and 4. Supralabials 1–3 subequal, supralabial 4 considerably larger than others of series, terminates well forward of posterior margin of ocular. Prefrontal and frontal subequal, both considerably larger than general body scales; supraocular subequal to prefrontal, in broad contact with nasal anteriorly and narrow contact with parietal posteriorly. Parietal width equivalent to two of body scales.

Microscopic scale organs present on all head scales, most abundant on ventral surfaces. Tubular glands not obvious but entire head is semi-translucent.

Right oviduct narrow, unconvoluted; ovary located 26 mm forward from vent, with numerous small follicles.

Hindgut with very short caecum, 4 mm in length, opens into gut 9 mm forward of vent.

Etymology
Longissimus (Latin); extremely long.

Comparison with other species
*Rhiphidophlops longissimus* is one of the most distinctive of all Australian typhlopids on account of its exceptionally elongate and slender body form, its unusually inflated rostrum and its almost

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Figure 5  Head of *Rhiphidophlops longissimus* sp. nov. illustrating basic form and details of scation in a) dorsal, b) lateral and c) ventral views.
complete lack of pigment. It is also unusual within the genus in having a greatly enlarged ocular scale which extends well posterior to the fourth supralabial.

Three other species have 16 midbody scale rows: *R. leptosoma* Robb, 1972; *R. minimus* (Kinghorn, 1929); and *R. neuma* Shea and Horner, 1997 [data for latter two species from Shea and Horner (1997)]. *Ramphotyphlops leptocephos* approaches *R. longissimus* in its degree of elongation (BW = 1.0–1.1% of SVL) and correspondingly high vertebral counts (558–720), but differs in having a less depressed head with an acute, chisel-edged rostrum and a nasal cleft that completely divides the nasal scale. *Ramphotyphlops minimus* is much less elongate (BW = 1.42–1.94% of SVL) and has far fewer longitudinal scale rows (381–457 ventral scales), a less depressed head and a complex body pattern, usually including longitudinal stripes. *Ramphotyphlops neuma* has a less elongate body form (BW = 1.08–1.75% of SVL), a lower number of longitudinal scale rows (520–589 ventral scales) and a less depressed head.

Several other species of *Ramphotyphlops* have longitudinal scale row counts which approach or even exceed the value in *R. longissimus*. *Ramphotyphlops troglodytes* Storr, 1981 has 641 ventral scales and also has a mildly depressed and bluntly-rounded head form, but it differs from *R. longissimus* in having 20 midbody scale rows and a nasal cleft that completely divides the nasal scale. Members of the *Ramphotyphlops gruppus* 'complex' (which most likely contains several species across northern Australia; pers. observ. and G. Shea, pers. comm.), have longitudinal scale row counts that may even exceed the value in *R. longissimus* [Storr (1981) records 790 ventral scales in the holotype of *R. gruppus* (Waite, 1918)]. However all members of this group have 18 midbody scale rows and a recurved rostral 'beak', and generally also have a darkly pigmented head and/or tail.

**Remarks**

*Ramphotyphlops longissimus* is an extremely distinctive typhlopid which is not obviously allied to any other known taxon. *Ramphotyphlops troglodytes* Storr, 1981 is perhaps most similar to *R. longissimus* in having a mildly depressed head and an extremely elongate body, but the two species differ in midbody scale counts and the configuration of the nasal cleft. The relative importance of these and other characters as phylogenetic indicators within *Ramphotyphlops* is not currently known.

The circumstances of capture of the holotype of *R. longissimus* are worthy of special mention. Apparently, the specimen was one of two individuals that were attached to the outer surface of a section of well-casing pulled from some considerable depth below ground during maintenance of an anode well at Bandicoot Bay on Barrow Island. One specimen was grabbed by Mr Lloyd Whitshed of Whitehead Resources Pty Ltd., while the second 'shot' back down the well and was lost. Because the animal looked more like a worm or eel than a snake, it was placed in a jar of water where it swam around for some time before being rescued by an environmental officer who recognised its true nature. The specimen was delivered several days later, still alive, to the Western Australian Museum.

The surficial geology of Barrow Island is comprised of Miocene limestones which are highly karstic. Drilling operations commonly 'punch' through deep caverns, often partially filled with red sediments; these might conceivably constitute part of the habitat of *R. longissimus*. Air temperatures in Barrow Island caverns are high (X = 28.9 °C; range = 26.6–33.1 °C, N = 19; W.F. Humphreys, pers. comm.), thus it would presumably be possible for individuals of this species to spend much, if not all, of their time in the subterranean environment. The only other typhlopid recorded from Barrow Island is *R. diversus anamolutes* (Montague, 1914), which is otherwise widely distributed throughout the Pilbara region; it is rarely encountered on the island.

Several of the more unusual features of *R. longissimus* may well be special adaptations to life within a subterranean environment of caverns and fissures. These include the degree of flattening of the head, the extreme slenderness of the body, the degree of reduction of the eyes and the almost complete lack of external pigmentation.

It is of interest to speculate on the possible diet of *R. longissimus*. Ant larvae and pupae form the major prey items of many if not all other Australian typhloids (Shine and Webb 1990). Hymenoptera are very poorly represented in Australian troglobitic faunas as elsewhere in the world, although surface-dwelling ants may incubate their eggs far below ground in such environments (W.F. Humphreys, pers. comm.). Unfortunately, the hindgut of the only known specimen of *R. longissimus* is empty, presumably as a consequence of the long period of captivity, and it is not possible to determine what the diet of this peculiar species might include.

*Ramphotyphlops garei* sp. nov.

Figures 6–8

**Material Examined**

**Holotype**

R124835 in the Western Australian Museum, an
adult female collected on 26 September 1995 by Mr Brian Bush at Cathedral Gorge, 30 km west of Newman, Western Australia, in 23 17'30"S, 119 28'E. Heart and liver frozen in liquid nitrogen and stored in -80°C ultrafreeze at the Western Australian Museum.

Paratypes

Australia: Western Australia: R102111 in the Western Australian Museum, an adult female collected as a road-kill in mid-April 1991 by Mr Lori Cane at Pannawonica in 21 39'S 116 20'E. Head crushed on right side. Heart and liver frozen in liquid nitrogen and stored in -80°C ultrafreeze at the Western Australian Museum. R129556 in the Western Australian Museum, an adult female collected at waste dump on Mt Whaleback in 23 20'57"S 119 41'30"E, by Mr K.J. Walker on 14/12/1985. R129571 in the Western Australian Museum, an adult male collected in Newman Townsite in 23 21'S 119 34'E by Mr K.J. Walker (no date provided but presumed 1985-1986).

Diagnosis

An elongate, moderately stout *Ramphotyphlops* with 24 midbody scale rows, a foreshortened head with snout bluntly rounded in lateral profile and from above, moderately high number of vertebral scales (430–448) and nasal cleft vertically dividing the nasal scale, originating from the second labial scale and terminating at the rostral scale on the dorsal surface of the head.

Description

An elongate and moderately stout-bodied species (see Figure 6).

SVL of females (N=3) 258–335 mm, of male 230 mm; tail length (without spine) of females 4.5–5.3 mm, of male 7.0 mm. Preserved body of female holotype 9.3 mm (width) by 9.5 mm (depth), of male 5.1 mm by 5.0 mm. Body width 2.89", 2.2% of SVL respectively.

Vertebral scales number 430–448 for females, 432 for male. Subcaudal scales (excluding conical spine) of females 12–13, of male 19.

Circumferential scale rows 24 along entire length of body.

In life, dorsal surface of head, body and tail an intense grey-brown, becoming paler on flanks; lateral colour ends abruptly, giving way to cream venter along jagged boundary. Number of pigmented scale rows is 14–15 along entire body, remaining rows immaculate. Head extensively pigmented. Undersurface of tail immaculate.

General head form and details of pigmentation and scalation illustrated in Figures 7–8. Head bluntly rounded in profile and from above, preocular region extremely foreshortened. Eyes conspicuous, positioned deep to anterodorsal portion of ocular scale. Rostral measures 3.0/mm from tip to posterior margin; very narrow
anteriorly and ventrally, expanding posterodorsally to maximum width of 1.6/mm; terminates just forward of line drawn across front of eyes. Nasals large, forming major part of anterior surface of head; broadly separated behind rostral by prefrontal. Nasal cleft originates from anterior end of second supralabial, curves around front of nostril then extends vertically onto upper surface of head, finally swinging posteromedially to contact posterolateral margin of rostral. Nasal scale thus completed divided into subequal anterior and posterior moieties. Preocular smaller than nasal, subequal to ocular, narrowly separated from prefrontal by intervening supraocular. Anterior suture of preocular intersects upper border of second supralabial well behind nasal cleft. Lower border of preocular overlaps supralabials 2–3. Ocular subequal to preocular. Ventral portion wedged between supralabials 3 and 4. Supralabials increase in size posteriorly; supralabial 4 projects behind posterior margin of ocular. Prefrontal large, equal to three body scales; deeply wedged between nasal and supraocular but fails to contact preocular. Supraocular subequal to prefrontal. Frontal not distinguishable from other scales of vertebral series. Parietal wide but strap-like, equal in width to three body scales.

Microscopic scale organs present on all head scales, only slightly more abundant on ventral and lateral surfaces than on dorsum. Tubular glands conspicuous around rostral and labial sutures.

The holotype, collected in late September, is gravid with an undetermined number of eggs. One of these has a length of 13 mm. Specimen R10211, collected in April, has an elongate but straplike right oviduct and a quiescent ovary. The single male specimen is reproducibly mature, with a convoluted efferent duct.

Hindgut of female R124835 with short rectal caecum, 13.8/mm in length, opening into gut 17.9 mm (32 scale rows) forward of vent. In male, rectal caecum measures 9.6 mm in length and opens 13.0 mm (36 scale rows) forward of vent.

Male specimen has short, narrow retrocloacal sacs which terminate 4 mm forward of the vent. Hemipenes not investigated.

Comparison with other species

The presence of short retrocloacal sacs in the referred male specimen demonstrates affinity with the genus *Ramphotyphlops* Fitzinger, 1843 as redefined by Robb (1966a,b) on the basis of features of the male reproductive tract. Other features, such as the supralabial imbrication pattern (Wallach 1993) and presence of a rectal caecum (Robb 1966b), further support this placement.

*Ramphotyphlops ganei* is perhaps most similar overall to *R. ligatus* with which it shares the relatively uncommon features of 24 midbody scale rows and continuation of the nasal cleft onto the upper surface of the snout. *Ramphotyphlops ligatus* (as defined by Storr (1981); work in progress suggests that it is composite, but without affecting the present comparisons) is less elongate than the new species and has fewer vertebral scales (296–355 in females), a less extremely foreshortened
head, a broader rostral scale, and a nasal cleft which originates at the first labial scale and terminates well short of the rostral scale. Representatives of the *R. ligatus* complex are found from the West Kimberley across northern Australia and south at least to northern New South Wales.

Three other species of *Ramphotyphlops* with 24 midbody scale rows are *R. yirrikalae* (Kinghorn, 1942) and *R. uguiostris* (Peters, 1867) from tropical Australia and *R. batillus* (Waite, 1894), known only from the holotype, reputedly from Wagga Wagga in New South Wales (see comments in McDowell, 1974). Each of these species is very different from *R. ganei*. *Ramphotyphlops yirrikalae* is a smaller, slender-built animal with a higher vertebral scale count (496; Northern Territory Museum 16855) and a nasal cleft which originates at the first labial scale and terminates at the nostril. *Ramphotyphlops uguiostris* has a very different head form (snout extended into sharp-edged beak, with broad rostral scale) and a nasal cleft which originates from the first labial and passes forwards.

Figure 8  Details of cephalic scalation of *Ramphotyphlops ganei* sp. nov. (paratype R102111) in a) dorsal, b) lateral views and c) ventral views.
through the nostril to contact the rostral scale. *Ramphotyphlops batillus* has a higher number of vertebral scales (557) and a very differently shaped rostrum.

Complete, nearly vertical division of the nasal scale is a rare condition in *Ramphotyphlops*, recorded previously only in *R. erucina* (Werner, 1901) from New Guinea (McDowell 1974) and as a variant in some Indonesian populations of *R. polygrammicus* (Smith 1927; Mertens 1930). *Ramphotyphlops erucina* differs from *R. ganei* in having a less foreshortened head, fewer midbody scale rows (20) and lower vertebral scale counts (292–319). Other taxa with a similarly oriented but incomplete nasal cleft are *R. ligatus*, *R. kimberleyensis* Storr, 1981, *R. polygrammicus* [possibly including "*R. torresianus*" (Boulenger, 1889)], *R. wiedii* (Boulenger, 1895) and *R. silvia* Ingram and Covacevich, 1994. Several of these taxa were grouped by McDowell (1974) as his "*Typhlim polygrammicus*" Group. *Ramphotyphlops kimberleyensis* and members of the *R. polygrammicus* complex have 22 midbody scale rows and a less foreshortened head than *R. ganei*, while *R. wiedii* and *R. silvia* have 20 midbody rows. None of these species appears to be closely related to *R. ganei*.

**Etymology**

Named for Mr Lori Gane, formerly of Pannawonica, schoolteacher, amateur herpetologist and collector of the first known specimen of *R. ganei* in 1991. Also in acknowledgement of his role in the events which lead to the recognition of the Pilbara Death Adder as a distinct species.

**Remarks**

*Ramphotyphlops ganei* does not appear to be particularly closely related to any other species in the genus. Probably its closest affinities are with *R. erucina* and members of the *R. ligatus* and *R. polygrammicus* complexes, but it differs from each of these taxa in significant aspects of cephalic form (e.g., the extreme foreshortening of the preorbital region) as well as in various features of scolation. At any rate, the biogeographic affinities of *R. ganei* appear to be with various northern Australian and New Guinean typhlopids, rather than with any southwestern or southern taxa.

*Ramphotyphlops ganei* has been collected at opposite ends of the Pilbara uplands, hence the species may occur over a substantial geographic range. However, the fact that it has not previously been collected surely implies either a general scarcity or a very discontinuous distribution. I tend towards the latter opinion and would hazard to suggest that the new species is associated with the moist microhabitats which exist in many of the deeper, better shaded gorges throughout the region.

**DISCUSSION**

Even though the three new taxa described above are each known from only one or a few specimens, I have no hesitation in describing each of them as a full species. *Ramphotyphlops longissimus* and *R. ganei* are particularly distinctive and cannot be confused with any other species; and while *Ramphotyphlops splendidus* is similar to *R. pinguis* in head morphology, it is readily distinguished by its more elongate body and correspondingly higher longitudinal scale count.

Of the three new species, only *R. ganei* is definitely affiliated with *Ramphotyphlops* on the basis of male reproductive anatomy. However, all three species are consistent with other *Ramphotyphlops* species in the presence of an intestinal caecum (Robb 1966b) and in supralabial imbrication pattern (Wallach 1993). They are also most conservatively placed within *Ramphotyphlops* on biogeographic grounds.

The addition of three new species of *Ramphotyphlops* to the herpetofauna of northwestern Australia almost doubles the number of typhlopid snakes recorded from the wider Pilbara region. It also takes to five the tally of regionally endemic typhlopids [the others are: *R. pilbarensis* Aplin and Donnellan, 1990; and *R. diversus annomytes* (Montague, 1914)] and further underscores the high level of endemism of this structurally complex upland subregion of the Australian arid zone (cf. Aplin and Donnellan 1991). The discovery of these new species highlights the very incomplete state of knowledge of the fossorial herpetofauna of northwestern Australia, in particular the Typhlopidae.

Also of special interest is the chance recovery of *R. longissimus* from below ground on Barrow Island, which surely rates as one of the most peculiar events in the history of Australian herpetology.

**ACKNOWLEDGEMENTS**

Special thanks to those individuals (mentioned above) who went against the current climate that frowns on 'collecting', and by so doing have made a valuable contribution to our knowledge of the diversity of Australian typhlopids. Thanks also to Mr Mark Cowan and Mr Brian Bush for providing photographs of two of the new species.

Vertebral scale row counts were taken by Mr Chris Taylor and Mr Mark Salotti of the W.A. Museum’s Department of Terrestrial Vertebrates. All of the illustrations are the work of Ms Nadine Guthrie of the School of Environmental Management, Edith Cowan University.
REFERENCES


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New species and new records of Hersiliidae from Australia
(Arachnida: Araneae: Hersiliidae). Sixth supplement
to the revision of the Australian Hersiliidae

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Abstract - Eight new species of Hersiliidae from various parts of Australia are described: Hersilia bifurcata sp. nov., H. wellswebberae sp. nov. (both from Northern Territory), H. longbottomi sp. nov., H. tenuifurcata sp. nov. (both Kimberley Division, Western Australia), Tainopsis hirsti sp. nov. (eastern central South Australia), T. kimberleyana sp. nov., T. minor sp. nov. (both Kimberley Division, Western Australia), and T. variatae sp. nov. (northern New South Wales). The hitherto unknown male of Tainopsis ediacara Baehr and Baehr, 1988 is described. According to new material from South Australia (including males and females from the same locality) and to new evidence, T. distinguenda Baehr and Baehr, 1992 is synonymized with T. revestyana Baehr and Baehr, 1987, T. triangularis Baehr and Baehr, 1993 is synonymized with T. facialis Baehr and Baehr, 1993, and T. nutri Baehr and Baehr, 1989 is synonymized with T. pseudocircumcinctus Baehr and Baehr, 1987. New records containing range extensions of several rare or rarely recorded hersiliid species are presented.

INTRODUCTION
Recent field work by a number of collectors, as well as examination of the Hersiliidae of the Museum and Art Gallery of the Northern Territory, Darwin, has produced a surprisingly large amount of additional hersiliid specimens from Australia since the last supplement in the ongoing revision of the Australian Hersiliidae (Baehr and Baehr, 1995). Although much of this material comprises previously described species, in some of these, range or even taxonomic status are insufficiently known, since few or even single records were available, or one sex was unknown until now. Hence, in the following, only those species are dealt with for which major taxonomic or chorological changes are to be made, and new records for these species are given in full length, whereas new records of the well known species Tainopsis brisbanensis, T. eucalypti, T. fickerti, T. fitzroyensis, T. occidentalis, and T. perthensis are omitted.

The discovery of four new species in each of Hersilia and Tainopsis further reveals that knowledge of the Australian hersiliid fauna is still unsatisfactory. Including the species described and synonymized in this paper, the Australian hersiliid fauna is now known to comprise 55 species, more than half of which have been described since the original revision (Baehr and Baehr, 1987). However, there are still some specimens of uncertain relations that might represent additional undescribed taxa of specific or subspecific rank, but still remain undescribed due to lack of additional material.


MATERIALS AND METHODS
The abbreviations and format of the descriptions follow previous papers (e.g. Baehr and Baehr, 1987, 1993a, 1993b, 1995); in the checklist the usual abbreviations for the states of Australia are used, together with abbreviations like n: northern, e: eastern, c: central, etc. The specimens examined in this paper are lodged in the following institutions: Collection B. Baehr, München (CBM); Museum and Art Gallery of the Northern Territory, Darwin (MNTD); South Australian Museum, Adelaide (SAMA); Western Australian Museum, Perth (WAM).

Measurements were made under a stereomicroscope using an ocular micrometer with up to 160x magnification.

TERMINOLOGY
Terminology in some parts has changed since our last paper on Australian hersiliids. What we called "embolus" of Hersilia species in previous papers, we now call "embolar apparatus" that is composed of the "embolus" (E) proper and the "embolar
apophysis” (EA), whereas the common base is the “stipes” (S). The former “tegular apophysis” (TA) is now more exactly called “median tegular apophysis” (MTA) (see Figures 1, 2).

In Tamopsis, where embolus and embolar apophysis commonly are less well differentiated, we keep on calling “lateral apophysis” (LA) the combined “embolus” and “embolar apophysis”, even though it is sometimes situated rather medially than laterally.

Genus Hersilia Audouin

Hersilia Audouin, 1826: 318. For further records see Roewer (1942), Brignoli (1983), Platnick (1989), and Baehr and Baehr (1987, 1993a, b, 1995).

Hersilia australiensis group

This group is characterized by the simple, medially hollowed MTA of the male palpus, the non-furcate embolar apparatus, the rather narrow, trapezoidal scapus of the female epigyne, and the very large median RS of the vulva that is situated rather closely together.

In Australia, this group includes only H. australiensis Baehr and Baehr, 1987. The group is also represented in New Guinea by H. madang Baehr and Baehr, 1993 and H. novuginnea Baehr and Baehr, 1993, the only Hersilia species known to occur in New Guinea, and perhaps also by the doubtful species H. pernix Kulczynski, 1911.

Hersilia australiensis Baehr and Baehr


New Material Examined

Australia: Northern Territory: 3 9, 4 immat., Litchfield Park-Aida Ck, 4 Sept 1992, Wells & Webber (MNTD); 1 9, Darwin, Stuart Park Vine Forest, April 1993, Webber (MNTD).

Remarks

This systematically rather isolated species is apparently restricted to the northernmost part of the Northern Territory. So far, it is the single representative of the australiensis-group in Australia.

Hersilia bifurcata group

The following four newly described species belong to the new bifurcata group that is mainly characterized by the deeply furcate embolar apparatus of the male palpus, the wide, subquadrate scapus of the female epigyne and the presence of two fairly small, widely separated RS in the vulva.

According to the shape of the female epigyne and vulva, the group also covers H. maine Baehr and Baehr, 1995, and perhaps also H. niuhi Baehr and Baehr, 1993, although the male embolar apparatus of the latter species is not deeply furcate.

Hersilia bifurcata sp. nov.

Figures 1, 2, 27

Material Examined

Holotype


Other Material Examined

Australia: Northern Territory: 1 immature 9 (MNTD) collected with the holotype is tentatively alluded to this species.

Diagnosis

Very large and extremely long-legged species, further characterized by PLS longer than abdomen, elongate male bulbus, deeply furcate, narrow embolar apparatus with elongate stipes.

Description

Male holotype

Measurements: Length: 9.3 mm; cephalothorax length: 3.5 mm; abdomen length: 5.8 mm; width: 3.3 mm. Legs: I: 62.22 mm; II: 57.81 mm; III: 17.10 mm; IV: 53.42 mm. Ratio: 1: 0.93: 0.27: 0.86. Ratio LB/LL: 0.15. PLS length: 6.5 mm; bS: 1.0 mm; tS: 5.5 mm. Length ratio PLS/abd: 1.12. Diameter of eyes: AME: 0.33 mm; ALE: 0.14 mm; PME: 0.29 mm; PLE: 0.28 mm. Eye ratio: AME/ALE 1: 0.42; AME/PME 1: 0.88; AME/PLE 1: 0.85.

Colour: Cephalothorax light yellow; border and radial stripes weakly mottled with dark. Sternum light yellow. Abdomen conspicuously mottled with dark, in anterior half with a dark median longitudinal stripe, laterally with some contrasting light and dark areas, posterior half with several dark transverse bars. Ventral side light. Legs and PLS yellow brown, legs almost unicolorous; PLS broadly annulate.

Cephalothorax: About circular, wider than abdomen. Carapace with median post-foveal depression. Eye area strongly raised, clypeus visible from above, almost as high as eye area. AME largest, PLE and PLE subequal to AME. Distance AME/AME 0.14 mm, < than 1/2 diameter of AME, distance AME/ALE 0.22 mm, c. 2/3 of diameter of AME. Distance PLE/PLE 0.13 mm, c. 1/2 of diameter of PLE, distance PLE/
Figures 1, 2 *Hersilia bifurcata* sp. nov., right male palpus. 1, ventral view; 2, lateral view. Scale line: = 0.5 mm.

**PLE 0.20 mm, c. 2/3 of diameter of PLE. Chelicerae c. 1.8 x as long as wide. Sternum heart-shaped, hirsute with fine long and short hairs.**

**Abdomen:** Elongate, considerably longer than wide, narrower than cephalothorax. Surface covered with short hairs, upper surface also rather densely covered with brown bristles, lateral and ventral surfaces with some elongate, light hairs. Dorsally with five pairs of DMP. VMP in a narrow v-shaped arrangement. PLS slightly longer than abdomen, is very elongate.

**Legs:** Very elongate, measurements see above. Metatarsus divided, distal part c. 1/2 as long as proximal part.

**Palpus:** Cymbium comparatively narrow and elongate, with 3 apical spines. Bulbus perceptibly longer than wide. MTA medially hollowed, distally with a ridge reaching to retrolateral margin. Median margin (MM), retrolateral margin (RM) and proximal margin (PM) sharply edged. Laterodistal border of MTA straight, near lateral angle convex. Proximal margin (PM) deeply hollowed, incision between MM and PM v-shaped.

**Seminal duct spirally coiled around MTA (MTA). Embolus (E) and embolar apophysis (EA) form together a deeply furcate structure. Embolus free, very elongate, narrow, rather straight. Embolar apophysis long, at apex curved inwards with a sharp, downcurved tip. Stipes (S) straight, as long as embolus. Embolus considerably shorter than embolar apophysis (Figures 1, 2).**

**Female**
Unknown.

**Etymology**
The name alludes to the deeply furcate embolus.

**Distribution and Habits**
Northern part of Northern Territory (Figure 27), known only from type locality. Holotype caught at M.V. light.

**Relationships**
*H. bifurcata* is a typical member of the *bifurcata-*
Figures 3-6  *Hersila wellswebberae* sp. nov. 3, right male palpus, ventral view; 4, right male palpus, lateral view; 5, epigyne, ventral view; 6, vulva, ventral view. Scale lines = 0.5 mm.
New species and records of Hersiliidae

Group, perhaps most closely related to *H. wellswebberae* sp. nov. and *H. longbottomi* sp. nov. It is distinguished from both by longer legs, elongate bulb of male palpus, and narrower embolar apparatus.

_Hersilia wellswebberae* sp. nov.

Figures 3–6, 27

Material Examined

**Holotype**


**Paratype**


Diagnosis

Large, long-legged species, further characterized by PLS longer than abdomen, circular bulb of male palpus, fairly wide embolar apparatus with short stipes, and narrow, at apex sharply incurved embolar apophysis.

Description

**Male holotype**

Measurements: Length: 8.2 mm; cephalothorax length: 3.4 mm; width: 3.4 mm; abdomen length: 4.7 mm; width: 3.3 mm. Legs: I: 52.93 mm; II: 52.02 mm; III: 14.01 mm; IV: 45.73 mm. Ratio: 1: 0.98: 0.26: 0.86. Ratio LB/LL: 0.16. PLS length: 5.8 mm; bS: 1.0 mm; tS: 4.8 mm. Length ratio PLS/abd: 1.23. Diameter of eyes: AME: 0.30 mm; ALE: 0.15 mm; PME: 0.28 mm; PLE: 0.28 mm. Eye ratio: AME/ALE 1: 0.50; AME/PME 1: 0.93; AME/PLE 1: 0.93.

Colour: Cephalothorax light yellow; border, radial stripes, and eye area weakly mottled with dark. Sternum light yellow. Abdomen in anterior half with a dark median longitudinal stripe, laterally conspicuously mottled with dark, posterior half with several dark transverse bars. Ventral side light. Legs and PLS yellow brown, legs almost unicolorous; PLS broadly annulate.

Cephalothorax: About circular, slightly wider than abdomen. Carapace with median post-foveal depression. Eye area strongly raised, clypeus visible from above, c. 2/3 x as high as eye area. AME the largest, PME and PLE subequal to AME. Distance AME/AME 0.13 mm, < than 1/2 diameter of AME, distance AME/ALE 0.19 mm, c. 2/3 of diameter of AME. Distance PME/PME 0.15 mm, slightly > 1/2 of diameter of PME, distance PME/PLE 0.20 mm, c. 2/3 of diameter of PLE. Chelicerae c. 1.8 x as long as wide. Sternum heart-shaped, hirsute with fine long and short hairs.

Abdomen: Elongate, considerably longer than wide, slightly narrower than cephalothorax. Surface covered with short hairs, upper surface also rather densely covered with brown bristles, lateral and ventral surfaces densely covered with elongate, light hairs. Dorsally with five pairs of DMP. VMP in a narrow v-shaped arrangement. PLS longer than abdomen, IS very elongate.

Legs: Very elongate, measurements see above. Metatarsus divided, distal part c. 1/2 as long as proximal part.

Palpus: Cymbium comparatively narrow and elongate, with 4 apical spines. Bulbus about circular, barely longer than wide. MTA rather elongate, reaching the margin of cymbium. Base feebly incised and with a ridge at distal half of margin only incurred towards the short, sharp median margin. Laterodistal border of MTA sinuate. PM deeply hollowed, not touching MM. Seminal duct spirally coiled around MTA. E and EA form together a deeply furcate structure. Embolus free, very elongate, narrow, rather straight. Embolar apophysis long, straight, at apex narrow, suddenly curved inwards, apex slightly curved down. Stipes < 2/3 of length of embolus, wide, sinuate. Embolus considerably shorter than embolar apophysis (Figures 3, 4).

**Female paratype**

Measurements: Length: 8.1 mm; cephalothorax length: 2.8 mm; width: 3.0 mm; abdomen length: 4.8 mm; width: 3.4 mm. Legs: I: 31.92 mm; II: 32.52 mm; III: 10.71 mm; IV: 29.89 mm. Ratio: 1: 1.02: 0.33: 0.94. Ratio LB/LL: 0.25. PLS length: 5.0 mm; bS: 0.9 mm; tS: 4.1 mm. Length ratio PLS/abd: 1.04. Diameter of eyes: AME: 0.25 mm; ALE: 0.14 mm; PME: 0.26 mm; PLE: 0.26 mm. Eye ratio: AME/ALE 1: 0.50; AME/PME 1: 0.56; AME/PLE 1: 1.04; AME/PLE 1: 1.04.

Colour: Ground pattern of colour similar to male, but abdomen less densely mottled and legs conspicuously annulate.

Cephalothorax: Subcircular, slightly wider than long, narrower than abdomen. Eye area strongly raised, clypeus visible from above, c. 2/3 as high as eye area. AME slightly smaller than PME and PLE. Distance AME/AME 0.20 mm, > 2/3 of diameter of AME, distance AME/ALE 0.20 mm, > 2/3 of diameter of AME. Distance PME/PME 0.15 mm, slightly > 1/2 diameter of PME, distance PME/PLE 0.18 mm, c. 2/3 of diameter of PLE. Chelicerae c. 1.8 x as long as wide. Sternum heart-shaped as in male.

Abdomen: Elongate, considerably longer than wide, slightly wider than cephalothorax. Pilosity and arrangement of DMP and VMP as in male. PLS about as long as abdomen, IS very elongate.

Legs: Elongate, though considerably shorter than in male, measurements see above. Metatarsus...
divided, distal part c. 2/5 as long as proximal part.

Epigyne: Very simple, with a quadrate scapus, considerably broader than long (Figure 5).

Vulva: With a circular, larger median RS and a smaller, elliptical lateral RS, and a short introductory duct with small median loop, ending lateromedially on scapus (Figure 6).

Etymology
The name is a patronym in honour of the collectors, Dr. A. Wells and Ms J. K. Webber.

Distribution and Habits
Western boundary of Arnhem Land, far Northern Territory (Figure 27). Paratype caught “on rocks”.

Relationships
H. wellsiuebberae is a typical member of the bifurcata-group, presumably most closely related to H. longbottomi sp. nov. from the Kimberley Division. It is mainly distinguished by longer PLS, short stipes of embolar apparatus, and embolar apophysis with sharply incurved apex.

Hersilia longbottomi sp. nov.
Figures 7–10, 27

Material Examined

Holotype

Paratype
Australia: Western Australia: 1 ♀, same data (S1466) (WAM 96/187).

Diagnosis
Rather large, moderately long-legged species, further characterized by PLS shorter than abdomen, circular male bulbus, deeply furcate, fairly wide embolar apparatus with elongate stipes, and wide, at apex evenly incurved embolar apophysis.

Description

Male holotype
Measurements: Length: 7.5 mm; cephalothorax length: 2.9 mm; width: 2.8 mm; abdomen length: 4.5 mm; width: 2.95 mm. Legs: I: 40.84 mm; II: 39.73 mm; III: 12.21 mm; IV: 28.33 mm. Ratio: 1: 0.97: 0.30: 0.94. Ratio LB/LL: 0.18. PLS length: 4.3 mm; bS: 0.8 mm; tS: 3.5 mm. Length ratio PLS/abd: 0.95. Diameter of eyes: AME: 0.35 mm; ALE: 0.13 mm; PME: 0.25 mm; PLE: 0.28 mm. Eye ratio: AME/ALE 1: 0.37; AME/PME 1: 0.71; AME/PLE 1: 0.80.

Colour: Cephalothorax light yellow; border, radial stripes, eye area, and clypeus weakly mottled with dark. Sternum light yellow. Abdomen very dark, in anterior half with a dark median longitudinal stripe, laterally conspicuously mottled with dark, with a pattern of two conspicuous transverse to semicircular light stripes, posterior half with several light and dark transverse bars. Ventral side light. Legs and PLS yellow brown; legs faintly, PLS distinctly annulate.

Cephalothorax: About circular, slightly narrower than abdomen. Carapace with median post-foveal depression. Eye area strongly raised, clypeus visible from above, c. 2/3 x as high as eye area. AME by far the largest, PME slightly smaller than PLE. Distance AME/AME 0.15 mm, < than 1/2 diameter of AME, distance AME/ALE 0.17 mm, c. 1/2 of diameter of AME. Distance PME/PME 0.16 mm, distinctly > 1/2 of diameter of PME, distance PME/PLE 0.20 mm, c. 2/3 of diameter of PLE. Chelicerae c. 1.8 x as long as wide. Sternum heart-shaped, hirsute with fine long and short hairs.

Abdomen: Elongate, considerably longer than wide, slightly wider than cephalothorax. Surface covered with short hairs, upper surface also rather densely covered with brown bristles, lateral and ventral surfaces densely covered with elongate, light hairs. Dorsally with five pairs of DMP. VMP in a narrow v-shaped arrangement. PLS shorter than abdomen, tS moderately elongate.

Legs: Elongate, measurements see above. Metatarsus divided, distal part c. 1/2 as long as proximal part.

Palpus: Cymbium comparatively narrow and elongate, with 5 apical spines. Bulbus about circular, barely longer than wide. MTA laterally not reaching the cymbium. Base incised, distally with a ridge reaching nearly the lateral tip of the retrolateral margin. Laterodistal border convex, near retrolateral tip deeply concave. PM deeply hollowed, separated from MM by a deep u-shaped incision. Seminal duct spirally coiled around MTA. E and EA form together a deeply furcate structure. Embolus free, fairly elongate, narrow, rather straight. EA elongate, curved, apex rather spatulate with rounded tip, evenly and widely incurved. Stipes elongate, as long as embolus, wide and medially concave. Embolus considerably shorter than embolar apophysis (Figures 7, 8).

Female paratype
Measurements: Length: 7.8 mm; cephalothorax length: 2.8 mm; width: 3.0 mm; abdomen length: 4.9 mm; width: 3.3 mm. Legs: I: 31.44 mm; II: 31.51 mm; III: 10.69 mm; IV: 29.70 mm. Ratio: 1: 1: 0.34: 0.95. Ratio LB/LL: 0.25. PLS length: 4.3 mm; tS: 0.8 mm; tS: 3.5 mm. Length ratio PLS/abd: 0.95. Diameter of eyes: AME: 0.35 mm; ALE: 0.13 mm; PME: 0.25 mm; PLE: 0.28 mm. Eye ratio: AME/ALE 1: 0.37; AME/PME 1: 0.71; AME/PLE 1: 0.80.

Colour: Cephalothorax light yellow; border, radial stripes, eye area, and clypeus weakly mottled with dark. Sternum light yellow. Abdomen very dark, in anterior half with a dark median longitudinal stripe, laterally conspicuously mottled with dark, with a pattern of two conspicuous transverse to semicircular light stripes, posterior half with several light and dark transverse bars. Ventral side light. Legs and PLS yellow brown; legs faintly, PLS distinctly annulate.

Cephalothorax: About circular, slightly narrower than abdomen. Carapace with median post-foveal depression. Eye area strongly raised, clypeus visible from above, c. 2/3 x as high as eye area. AME by far the largest, PME slightly smaller than PLE. Distance AME/AME 0.15 mm, < than 1/2 diameter of AME, distance AME/ALE 0.17 mm, c. 1/2 of diameter of AME. Distance PME/PME 0.16 mm, distinctly > 1/2 of diameter of PME, distance PME/PLE 0.20 mm, c. 2/3 of diameter of PLE. Chelicerae c. 1.8 x as long as wide. Sternum heart-shaped, hirsute with fine long and short hairs.

Abdomen: Elongate, considerably longer than wide, slightly wider than cephalothorax. Surface covered with short hairs, upper surface also rather densely covered with brown bristles, lateral and ventral surfaces densely covered with elongate, light hairs. Dorsally with five pairs of DMP. VMP in a narrow v-shaped arrangement. PLS shorter than abdomen, tS moderately elongate.

Legs: Elongate, measurements see above. Metatarsus divided, distal part c. 1/2 as long as proximal part.

Palpus: Cymbium comparatively narrow and elongate, with 5 apical spines. Bulbus about circular, barely longer than wide. MTA laterally not reaching the cymbium. Base incised, distally with a ridge reaching nearly the lateral tip of the retrolateral margin. Laterodistal border convex, near retrolateral tip deeply concave. PM deeply hollowed, separated from MM by a deep u-shaped incision. Seminal duct spirally coiled around MTA. E and EA form together a deeply furcate structure. Embolus free, fairly elongate, narrow, rather straight. EA elongate, curved, apex rather spatulate with rounded tip, evenly and widely incurved. Stipes elongate, as long as embolus, wide and medially concave. Embolus considerably shorter than embolar apophysis (Figures 7, 8).
New species and records of Hersiliidae

Figures 7–10 *Hersilia longbottomi* sp. nov.: 7, right male palpus, ventral view; 8, right male palpus, lateral view; 9, epigyne, ventral view; 10, vulva, ventral view. Scale lines: = 0.5 mm.

0.9 mm; tS: 3.4 mm. Length ratio PLS/abd: 0.88. Diameter of eyes: AME: 0.30 mm; ALE: 0.14 mm; PME: 0.28 mm; PLE: 0.28 mm. Eye ratio: AME/ALE 1: 0.47; AME/PME 1: 0.93; AME/PLE 1: 0.93.

Colour: Ground pattern similar to male, but abdomen more irregularly mottled and legs much more conspicuously annulate.

Cephalothorax: Subcircular, slightly wider than long, narrower than abdomen. Eye area strongly raised, clypeus visible from above, c. 2/3 as high as eye area. AME slightly larger than PME and PLE. Distance AME/AME 0.14 mm, slightly < 1/2 of diameter of AME, distance AME/ALE 0.16 mm, slightly > 1/2 of diameter of AME. Distance PME/PLE 0.15 mm, slightly > 1/2 diameter of PME, distance PME/PLE 0.19 mm, c. 2/3 of diameter of PLE. Chelicerae c. 1.8 x as long as wide. Sternum as in male.

Abdomen: Elongate, considerably longer than wide, wider than cephalothorax. Pilosity and arrangement of DMP and VMP as in male. PLS perceptibly shorter than abdomen, tS moderately elongate.

Legs: Elongate, though considerably shorter than in male, measurements see above. Metatarsus divided, distal part c. 2/5 as long as proximal part.

Epigyne: Very simple, with a quadrate scapsus, considerably broader than long (Figure 9).

Vulva: With a large, somewhat kidney-shaped median RS and a slightly smaller, egg-shaped
lateral RS, and a short introductory duct with large median loop, ending in front of apex of the scapus (Figure 10).

**Etymology**
The name is a patronym in honour of the collector, A. F. Longbottom.

**Distribution and Habits**
Kimberley Division, northwestern Australia (Figure 27), known only from type locality. Collecting circumstances unknown.

**Relationships**
*H. longbottomi* is a typical member of the *bifuircata*-group, presumably most closely related to *H. wellswebberae* sp. nov. It is distinguished by shorter PLS, elongate base of embolus, and wider conductor with evenly incurved apex.

**Hersilia tenuifurcata** sp. nov.
Figures 11-14, 27

**Material Examined**

**Holotype**

**Paratype**
Australia: Western Australia: 1 ♀, same data (WAM 96/189).

**Diagnosis**
Rather large, moderately long-legged species, further characterized by PLS longer than abdomen, circular male bulb, very deeply furcate, narrow embolar apparatus with short and narrow stipes, and narrow embolar apophysis at apex evenly.

**Description**

**Male holotype** (partly worn specimen)
Measurements: Length: ?; cephalothorax length: 2.85 mm; width: 3.0 mm; abdomen length: ?; width: ?. Legs: I: 38.30 mm; II: 37.28 mm; III: 11.69 mm; IV: 35.41 mm. Ratio: 1: 0.97: 0.31: 0.92. Ratio LB/LL: ?. PLS length: 4.4 mm; bS: 0.8 mm; tS: 3.6 mm. Length ratio PLS/abd: ?. Diameter of eyes: AME: 0.315 mm; ALE: 0.13 mm; PME: 0.26 mm; PLE: 0.275 mm. Eye ratio: AME/AME 1: 0.41; AME/PME 1: 0.83; AME/PLE 1: 0.87.

Colour: Rather faded, cephalothorax light yellow; border, radial stripes, and eye area weakly mottled with dark. Sternum light yellow. Abdomen in anterior half with a dark median longitudinal stripe, laterally mottled with dark, posterior half with several light and dark transverse bars. Ventral side light. Legs and PLS yellow brown, weakly annulate.

Cephalothorax: About circular. Carapace with median post-foveal depression. Eye area moderately raised, clypeus visible from above, slightly > than half as high as eye area. AME by far the largest, PME slightly smaller than PLE. Distance AME/AME 0.15 mm, < than 1/2 diameter of AME, distance AME/ALE 0.20 mm, slightly < 2/3 of diameter of AME. Distance PME/PME 0.16 mm, distinctly > 1/2 of diameter of PME, distance PME/PLE 0.20 mm, slightly > 2/3 of diameter of PLE. Chelicerae c. 1.8 x as long as wide. Sternum heart-shaped, hirsute with fine long and short hairs.

Abdomen: Elongate, presumably considerably longer than wide. Surface covered with short hairs, upper surface also rather densely covered with brown bristles, lateral and ventral surfaces densely covered with elongate, light hairs. Dorsally with five pairs of DMP. VMP in a narrow v-shaped arrangement. PLS apparently slightly longer than abdomen, tS rather elongate.

Legs: Elongate, measurements see above. Metatarsus divided, distal part slightly > 1/2 as long as proximal part.

Palpus: Cymbium comparatively narrow and elongate at apex, broad at base, with 3 apical spines. Bulbus about circular, as long as wide. MTA laterally not reaching the cymbium. Base incised and with weak ridge reaching nearly the lateral angle of the retrolateral margin. Laterodistal border slightly concave. MM angulate, slightly hook-shaped, partly covered by the deeply hollowed PM. Seminal duct spirally coiled around MTA. E and EA form together a deeply furcate structure. Embolus free, very elongate, narrow though basally widened, rather curved. EA remarkably narrow, rather straight, at apex narrow, evenly and very widely curved inwards. Stipes narrow, short, only 1/3 of length of embolus, medially markedly concave. Embolus not much shorter than than embolar apophysis (Figures 11, 12).

**Female paratype**
Measurements: Length: 7.6 mm; cephalothorax length: 2.9 mm; width: 3.2 mm; abdomen length: 4.4 mm; width: 3.3 mm. Legs: I: 32.19 mm; II: 31.28 mm; III: 10.88 mm; IV: 29.07 mm. Ratio: 1: 0.97: 0.34: 0.90. Ratio LB/LL: 0.24. PLS length: 4.7 mm; bS: 0.9 mm; tS: 3.8 mm. Length ratio PLS/abd: 1.07.

Diameter of eyes: AME: 0.30 mm; AL: 0.16 mm; PME: 0.29 mm; PLE: 0.29 mm. Eye ratio: AME/AL: 1: 0.53; AME/PME: 1: 0.97; AME/PLE: 1: 0.97.

Colour: Ground pattern of colour similar to male, but abdomen more contrastingly mottled with more extended whitish areas in antero-lateral parts.
New species and records of Hersiliidae

Figures 11-14  *Hersilia tenuifurcata* sp. nov. 11, right male palpus, ventral view; 12, right male palpus, lateral view; 13, epigyne, ventral view; 14, vulva, ventral view. Scale lines: = 0.5 mm.

of upper surface, and legs more conspicuously annulate.

Cephalothorax: Subcircular, slightly wider than long, barely narrower than abdomen. Eye area strongly raised, clypeus visible from above, slightly < 2/3 as high as eye area. AME slightly larger than PME and PLE. Distance AME/AME 0.16 mm, slightly > 1/2 of diameter of AME, distance AME/ALE 0.19 mm, slightly < 2/3 of diameter of AME.

Abdomen: Elongate, considerably longer than wide, slightly wider than cephalothorax. Pilosity and arrangement of DMP and VMP as in male.

Distance PME/PME 0.16 mm, slightly > 1/2 diameter of PME, distance PME/PLE 0.22 mm, > 2/3 of diameter of PLE. Chelicerae c. 1.8 x as long as wide. Sternum as in male.

Abdomen: Elongate, considerably longer than wide, slightly wider than cephalothorax. Pilosity and arrangement of DMP and VMP as in male. PLS slightly longer than abdomen, tS rather elongate.
Legs: Elongate, though considerably shorter than in male, measurements see above. Metatarsus divided, distal part c. 2/5 as long as proximal part.

Epigyne: Very simple, with an about quadrate scapus, the posterior border of which is gently convex, scapus considerably broader than long (Figure 13).

Vulva: With a larger, apically straight median RS and a slightly smaller, about egg-shaped lateral RS, and a short introductory duct with small median loop, ending close to apex of the scapus (Figure 14).

Etymology
The name alludes to the deeply furcate, delicate embolus.

Distribution and Habits
Kimberley Division, northwestern Australia (Figure 27), known only from type locality. Collecting circumstances unknown.

Relationships
*II. tenuifurcata* is a typical member of the *bifurcata-*group, presumably less closely related to any of the other three newly described species than they are.

Identification
For identification of the four new species, the key to the Australian species of *Herailia* in the fifth supplement (Baehr and Baehr, 1995) should be replaced by the following one:

1. Males .................................................. 2
2. Females .................................................. 7

3. Embolar apparatus of male palpus at apex barely furcate (Baehr and Baehr, 1987 Figures 1d, e; Baehr and Baehr, 1993a Figure 1) ................................................................. 3

4. Embolar apparatus of male palpus at apex deeply furcate (Figures 1-4, 7, 8, 11, 12) ..... 4

5. Median apophysis of male palpus simply spoon-shaped, without angulate median, retrolateral and proximal margins; flagellum of embolus short (Baehr and Baehr, 1987 Figures 1d, e) .... *australiensis* Baehr and Baehr

6. Median apophysis of male palpus complex, with angulate median (MM), retrolateral (RM) and proximal margins (PM) and with a basal ridge; flagellum of embolus elongate (Baehr and Baehr, 1993a Figure 1) ................................................................. *mimbi* Baehr and Baehr

7. Bulbus of male palpus rather circular and embolar apparatus wider and shorter and stipes short, or stipes elongate but then embolar apophysis distinctly curved (Figures 3, 4, 7, 8, 11, 12) ................................................................. 5

8. Vulva: With a larger, apically straight median RS and a slightly smaller, about egg-shaped lateral RS, and a short introductory duct with small median loop, ending close to apex of the scapus (Figure 14).

9. Embolar apparatus of male palpus very deeply furcate and embolus only slightly shorter than embolar apophysis (Figures 11, 12) ................................................................. *tenuifurcata* sp. nov.

10. Embolar apparatus of male palpus less deeply furcate and embolus distinctly shorter than embolar apophysis (Figures 3, 4, 7, 8) ..... 6

11. Stipes of embolar apparatus of male palpus short and wide, embolar apophysis straight, apex narrow, acute, suddenly incurved (Figures 3, 4). Spinnerets elongate, longer than abdomen ........ *wellswebberae* sp. nov.

12. Stipes of embolar apparatus of male palpus longer and narrower, embolar apophysis curved, apex wide, spatulate, rounded at tip, evenly incurved (Figures 7, 8). Spinnerets shorter, distinctly shorter than abdomen .... ............... *longbottomi* sp. nov.

13. Female epigyne with narrow, trapezoidal median scapus; median RS of vulva very large, situated close together (Baehr and Baehr, 1987 Figures 2d, e) .................................................................

14. Female epigyne with wide, quadrate median scapus; median RS of vulva much smaller, widely separated (Figures 6, 10, 14; Baehr and Baehr, 1993a Figures 3, 4; Baehr and Baehr, 1995 Figures 1d, e) .... 8

15. Median scapus of female epigyne apically slightly convex, lateral plates more advanced than scapus; median RS of vulva short and compact, at apex conspicuously transverse (Figures 13, 14) .... *tenuifurcata* sp. nov.

16. Median scapus of female epigyne apically straight or slightly concave, scapus at same level with lateral plates; median RS of vulva differently shaped, but when at apex conspicuously transverse, then elongate (Figures 5, 6, 9, 10; Baehr and Baehr, 1993a Figures 3, 4; Baehr and Baehr, 1995 Figures 1d, e) ................................................................. 9

17. Beginning of introductory duct on distal part of scapus, lateral RS narrow, coiled (Baehr and Baehr, 1993a Figure 4) ................................................................. *mimbi* Baehr and Baehr

18. Beginning of introductory duct in middle of scapus or somewhat removed from distal part, lateral RS larger, not coiled (Figures 6, 10; Baehr and Baehr, 1995 Figure 1e) ................................................................. 10

19. Vulva with two elongate, rather rectangular
New species and records of Hersiliidae

RS, introductory ducts medially with large loops rather situated close together (Baehr and Baehr, 1995 Figure 1e) .......................................................... 11

Vulva with two shorter, circular or elliptical loops or loops widely separated (Figures 6, 10) .......................................................... 11

11. Median RS kidney-shaped, elongate, introductory ducts medially with large loops (Figure 10) .............................................. longbottomi sp. nov.

Median RS circular, introductory ducts medially with small loops (Figure 6) ............... wellswebberae sp. nov.

Genus Tamopsis Baehr and Baehr


Type species

*Tama eucalypti* Rainbow, 1900, by original designation.

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**Tanopsis queenslandica group**

**Tanopsis hirsti** sp. nov.

Figures 15, 16, 27

Material Examined

*Holotype*  

Diagnosis

Medium-sized, short legged species, further characterized by PLS shorter than abdomen, MTA narrow, deeply incised, LA near apex on rear side with conspicuous sharp bend, and with a deep incision at apex.

Description

*Male holotype*

Measurements: Length: 4.35 mm; cephalothorax length: 1.75 mm; width: 1.72 mm; abdomen length: 2.50 mm; width: 2.15 mm. Legs: I: 11.48 mm; II: 10.95 mm; III: 4.40 mm; IV: 10.66 mm. Ratio: 1: 0.95: 0.38: 0.93. Ratio LB/LL: 0.38. PLS length: 2.30

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**Figures 15-16**  
*Tanopsis hirsti* sp. nov. 15, right male palpus, ventral view; 16, right male palpus, lateral view. Scale lines: = 0.5 mm.
mm; bS: 0.45 mm; tS: 1.85 mm. Length ratio PLS/abd: 0.92. Diameter of eyes: AME: 0.22 mm; ALE: 0.075 mm; PME: 0.20 mm; PLE: 0.20 mm. Eye ratio: AME/ALE 1: 0.34; AME/PME 1: 0.91; AME/PLE 1: 0.91.

Colour: Cephalothorax light yellow; border and radial stripes largely mottled with dark, eye area dark, clypeus dark, with two small reddish paramedian spots only, chelicerae largely dark. Sternum light yellow. Abdomen in anterior half with a dark median longitudinal stripe, laterally densely mottled, in parts even longitudinally striped with dark, posterior third with several light and dark transverse bars. Ventral side light. Legs and PLS yellow brown, legs distinctly annulate, ventral surface of femora longitudinally striped, PLS with several dark rings and narrow dark border at base.

Cephalothorax: About circular. Carapace with median post-foveal depression. Eye area depressed, clypeus barely visible from above, slightly > half as high as eye area. AME the largest, PME as large as PLE. Distance AME/AME 0.07 mm, c. 1/3 of diameter of AME, distance AME/ALE 0.09 mm, wider than diameter of ALE. Distance PME/PME 0.045 mm, slightly > than 1/4 of diameter of PME, distance PME/PLE 0.14 mm, c. as wide as 2/3 of diameter of PLE. Chelicerae c. 1.8 x as long as wide. Sternum pentagonal, with some hairs.

Abdomen: Moderately elongate, slightly longer than wide, rather triangular, wider than cephalothorax. Surface covered with short hairs, upper surface also rather densely covered with brown bristles, lateral and ventral surfaces covered with elongate, light hairs. Dorsally with five pairs of circular DMP. VMP in a narrow v-shaped arrangement. PLS slightly shorter than abdomen, tS rather elongate.

Legs: Comparatively short, III relatively elongate.

Palpus: MTA strongly contorted, oblique. Apex deeply incised, narrow, with a large membranous area within. LA elongate, markedly contorted, channeled for reception of embolus, near apex on rear side with conspicuous sharp bend. Apex deeply incised (Figures 15, 16).

Female
Unknown.

Etymology
Named in honour of the collector, D. Hirst.

Distribution and Habits
Eastern inland South Australia (Figure 27), known only from type locality. Holotype collected at night on Eucalyptus gillii.

Relationships
T. hirsti is closely related to T. revesbyana Baehr and Baehr from southwestern Australia and southern South Australia and is distinguished only by minor differences in shape of MTA and I.A.

Tamopsis facialis Baehr and Baehr
Figure 28

Tamopsis facialis Baehr and Baehr, 1993a: 365; Baehr and Baehr, 1995: 110.


New Material Examined
Australia: Western Australia: 1 ♂, East Victoria Park, Cardif St., 31°59'S, 115°54'E, 16 Dec. 1995, J. M. Waldock, ex eucalypt in garden (WAM 96/182).

South Australia: 1 ♂, 1 ♀, Mallee nr creek, Mt Farview, Paney Station, 32°34'S, 135°35'E, 8 Dec 1989, coll. & ident D. Hirst: Tamopsis facialis (SAMA N1994215-6); 1 ♂, Mt Farview, Paney Station, 32°34'S, 135°35'E, 8 Dec 1989, coll. & ident D. Hirst: Tamopsis facialis (SAMA N1994217); 1 ♀, Slopes of Scrubby Peak, 32°31'S, 135°19'E, 12 Dec 1989, coll. & ident D. Hirst: Tamopsis facialis (SAMA N1994218).

Remarks
T. facialis was described from two males collected in Western Australia, T. triangularis from one female from southern New South Wales. Males and females collected at the same locality in South Australia now demonstrate that both names refer to the same species that possesses very characteristic male palpus and female vulva. However, females of this species considerably differ from the males by much larger size and characteristically triangular shape of abdomen. This is likewise present in the newly recorded female from Perth (WAM 96/182) that is plainly associated with T. facialis. Both names are thus herewith synonymized and the valid name is T. facialis, as the description of this species was given several pages before that of T. triangularis and T. facialis was described from male specimens.

This species is now recorded from Western Australia south of Great Sandy Desert, through the southernmost part of South Australia including Kangaroo Island, and from southern New South Wales (Figure 28).

Tamopsis minor sp. nov.
Figures 17-20, 28

Material Examined
Holotype
♂, Australia: Western Australia: Drysdale River
New species and records of Hersiliidae

Figures 17–20  *Ramopsis minor* sp. nov. 17, right male palpus, ventral view; 18, right male palpus, lateral view; 19, epigyne, ventral view; 20, vulva, ventral view. Scale lines: = 0.5 mm.


Paratype

Australia: Western Australia: 1 ♂, Drysdale River Stn, 15°42'S 126°23'E, 17 June 1993, A. F. Longbottom (S. 1240) on diesel fuel tank (WAM 96/177).

Diagnosis

Rather small, moderately short legged species, further characterized by PLS as long as or longer than abdomen, MTA narrow, deeply incised, LA near apex on rear side with conspicuous sharp bend, and with a deep incision at apex. Further distinguished from relative *T. facialis* Baehr and Baehr by lesser size, circular rather than triangular shape of female abdomen, longer legs, irregularly shaped seminal duct, less bulbbose base of LA, anteriorly less curved lateral plate of female epigyne, larger and more conspicuously ridged plate above lateral slit.

Description

Male holotype

Measurements: Length: 3.25 mm; cephalothorax length: 1.45 mm; width: 1.45 mm; abdomen length: 1.92 mm; width: 1.60 mm. Legs: I: 9.40 mm; II: 9.75 mm; III: 3.85 mm; IV: 9.05 mm. Ratio: I: 1.04: 0.41: 0.96. Ratio LB/LL: 0.33. PLS length: 1.85 mm; bS: 0.40 mm; tS: 1.45 mm. Length ratio PLS/abd: 0.96. Diameter of eyes: AME: 0.165 mm; ALE: 0.08 mm; PME: 0.14 mm; PLE: 0.15 mm. Eye ratio: AME/ALE: 1: 0.48; AME/PLE 1: 0.85; AME/PME 1: 0.91.

Colour: Cephalothorax light yellow; border and radial stripes slightly mottled with dark, eye area barely dark, clypeus light, with narrow dark median stripe, chelicerae light. Sternum light yellow. Abdomen in anterior half with a dark
median longitudinal stripe, laterally densely mottled with dark and with some rather conspicuous light stripes, posterior third with several light and dark transverse bars. Ventral side light. Legs and PLS yellow brown, legs very lightly annulate; PLS almost completely light.

Cephalothorax: About circular. Carapace with median post-foveal depression. Eye area depressed, clypeus barely visible from above, slightly > half as high as eye area. AME the largest, PME slightly smaller than PLE. Distance AME/AME 0.06 mm, slightly > 1/3 of diameter of AME, distance AME/ALE 0.10 mm, wider than diameter of ALE. Distance PME/PME 0.055 mm, > than 1/3 of diameter of PME, distance PME/PLE 0.11 mm, c. as wide as 2/3 of diameter of PLE. Chelicerae c. 1.8 X as long as wide. Sternum pentagonal, with some hairs.

Abdomen: Fairly elongate, distinctly longer than wide, elliptical, wider than cephalothorax. Surface covered with short hairs, upper surface also rather densely covered with brown bristles, lateral and ventral surfaces covered with elongate, light hairs. Dorsally with five pairs of circular DMP. VMP in a narrow v-shaped arrangement. PLS slightly shorter than abdomen, tS rather elongate.

Legs: Comparatively short, though relatively longer than in males of T. facialis Baehr and Baehr, III relatively elongate, measurements see above.

Palpus: Seminal duct bordering the bulbus irregularly curved. MTA strongly contorted, deeply incised at apex, inner part of incision slender, outer part convex, laterally with sharp edge. LA elongate, also contorted, apex deeply incised, in front of apex markedly notched on both sides. Base laterally with a lamella, basal half conspicuously notched (Figures 17, 18).

Female paratype

Measurements: Length: 4.35 mm; cephalothorax length: 1.75 mm; width: 1.80 mm; abdomen length: 2.55 mm; width: 2.68 mm. Legs: I: 10.98 mm; II: 10.95 mm; III: 4.60 mm; IV: 10.48 mm. Ratio: I: 1: 0.42: 0.95. Ratio LB/LI: 0.40, PLS length: 2.85 mm; bS: 0.50 mm; tS: 2.35 mm. Length ratio PLS/abd: 1.12. Diameter of eyes: AME: 0.18 mm; ALE: 0.06 mm; PME: 0.175 mm; PLE: 0.18 mm. Eye ratio: AME/ALE 1: 0.33; AME/PME 1: 0.97; AME/PLE 1: 1.

Colour: Cephalothorax as in male, though more conspicuously mottled. Clypeus largely light without conspicuous pattern, chelicerae mostly light. Abdomen as in male, laterally of dark median stripe largely whitish, inconspicuously mottled. Legs distinctly annulate, PLS only faintly annulate.

Cephalothorax: Shape as in male. AME about as large as PME and PLE. Distance AME/AME 0.075 mm, < half of diameter of AME, distance AME/

Tamopsis gibbosa Baehr and Baehr

Figure 27

Tamopsis gibbosa Baehr and Baehr, 1993a: 372.

New Material Examined

Australia: South Australia: 1♀, Middleback

Remarks
The female vulva of this species is very characteristic, although the newly recorded specimen lacks the hump in the middle of the abdomen present in the holotype. The new record considerably enlarges the recorded range into the Eyre Peninsula in southern South Australia (Figure 27). Apparently, T. gibbosa is another species distributed through the whole or at least through large parts of the southern semiarid belt crossing the Nullarbor Plain.

Tamopsis raveni Baehr and Baehr


New Material Examined

Remarks
The new records corroborate the presence of T. raveni in temperate South Australia, although the species was originally described from southeast Queensland. Records from the large area between are thus far unknown.

Tamopsis reevesbyana Baehr and Baehr


New Material Examined

Remarks
T. reevesbyana was so far known only from the female holotype collected on Reevesby Island off the coast of South Australia, whereas T. distinguenda was described from southwestern Australia where it was repeatedly recorded (Baehr and Baehr, 1992, 1993a, 1995). The two known females of the latter species clearly show the presence of a (smaller) dorsal RS, whereas in the single available female of T. reevesbyana the dorsal RS is apparently absent. This was the reason to distinguish the females of both species that until now had also different ranges. Now, several males and females are available from a limited area in South Australia, some of which were captured even at the same locality. The male palpus of these specimens is identical with that of T. distinguenda, whereas the female vulva is similar in shape to that of both T. reevesbyana and T. distinguenda. In some of the females a second (dorsal) RS is clearly visible, in some it is not. So we guess that the holotype of T. reevesbyana is a specimen in which the dorsal RS is less distinct than usual, and therefore we think that both names are synonymous and only one rather widespread species is involved (Figure 29).

Tamopsis nanutarrae group

Tamopsis transiens Baehr and Baehr

Figure 28

Tamopsis transiens Baehr and Baehr, 1992: 70.

New Material Examined

Remarks
Until the record mentioned above, this species was known from the interior of southwestern Australia and from northwestern Victoria. The new record enlarges the range of this species to the north and corroborates that it is a southern inland species (Figure 28).
**Tamopsis kimberleyana group**

Newly erected group for *T. kimberleyana* sp. nov. (below) that is presumably next related to the *nanutarrae* group by virtue of absence of a scopula-like organ and roof-like hook on ventral border of MTA, and by the rather simply shaped LA. Apart from those primitive character states the group is characterized by LA even simpler than in the *nanutarrae* group but more complex than in the *arnhemensis* group, and by the conspicuous large hook-shaped process that arises within the membraneous area of the MTA.

**Tamopsis kimberleyana** sp. nov.

**Material Examined**

**Holotype**


**Paratype**

Australia: Western Australia: 1 ♂, Gibb River Rd, 25 km E of Gregory’s Jump, 30 April 1993, coll. A. F. Longbottom, on trailer while camping (S. 1187) (WAM 96/184).

**Diagnosis**

Small, moderately long-legged species, further characterized by PLS shorter than abdomen, MTA without scopula-like organ but with large hook within membraneous area, and simply shaped LA without any deep incisions at apex.

**Description**

**Male holotype**

Measurements: Length: 3.1 mm; cephalothorax length: 1.32 mm; abdomen length: 1.68 mm; width: 1.32 mm. Legs: I: 12.04 mm; II: 11.16 mm; III: 3.67 mm; IV: 9.73 mm. Ratio: 1: 0.93: 0.30: 0.81. Ratio LB/LL: 0.26. PLS length: 1.4 mm; bS: 0.4 mm; tS: 1.0 mm. Length ratio PLS/abd: 0.83. Diameter of eyes: AME: 0.16 mm; ALE: 0.06 mm; PME: 0.125 mm; PLE: 0.125 mm. Eye ratio: AME/ALE 1: 0.38; AME/PME 1: 0.78; AME/PLE 1: 0.78.

Colour: Cephalothorax light yellow; border and radial stripes largely mottled with dark, eye area dark, clypeus yellow, in middle with broad dark stripe, chelicerae largely dark. Sternum light yellow. Abdomen in anterior half with a dark median longitudinal stripe, laterally rather feebly mottled with dark, posterior third with several light and dark transverse bars, general dorsal pattern of abdomen bistriate. Ventral side light.

![Figures 21, 22](image-url) Tamopsis kimberleyana sp. nov. 21, right male palpus, ventral view; 22, right male palpus, lateral view. Scale lines = 0.5 mm.
New species and records of Hersiliidae

Legs and PLS yellow brown, legs distinctly annulate; PLS with two conspicuous dark rings, base of PLS with narrow dark border.

Cephalothorax: About circular. Carapace with median post-foveal depression. Eye area markedly raised, clypeus visible from above, almost as high as eye area. AME by far the largest, PME as large as PLE. Distance AME/AME 0.09 mm, slightly > than 1/2 diameter of AME, distance AME/ALE 0.06 mm, about as wide as diameter of ALE. Distance PME/PME 0.05 mm, slightly > than 1/3 of diameter of PME, distance PME/PLE 0.08 mm, slightly < than 2/3 of diameter of PLE. Chelicerae c. 1.8 x as long as wide. Sternum pentagonal, with some hairs.

Abdomen: Fairly elongate, considerably longer than wide, wider than cephalothorax. Surface covered with short hairs, upper surface also rather densely covered with brown bristles, lateral and ventral surfaces covered with elongate, light hairs. Dorsally with five pairs of circular DMP. VMP in a narrow v-shaped arrangement. PLS considerably shorter than abdomen, tS moderately elongate.

Legs: Moderately elongate, measurements see above.

Palpus: MTA strongly contorted. Apex with a large membraneous area but without a scopula-like organ within. Ventral border without roof-like hook, but membraneous area with a strong, very conspicuous hook. LA elongate but little contorted. Apex simple, without any perceptible incisions (Figures 21, 22).

**Male paratype**

Measurements: Length: 3.45 mm; cephalothorax length: 1.48 mm; width: 1.32 mm; abdomen length: 1.88 mm; width: 1.55 mm. Legs: I: 11.78 mm; II: 11.24 mm; III: 3.61 mm; IV: 9.68 mm. Ratio: I: 0.95; 0.31: 0.82. Ratio LB/LL: 0.29. PLS length: 1.48 mm; bS: 0.40 mm; tS: 1.48 mm. Length ratio PLS/abd: 0.79. Diameter of eyes: AME: 0.17 mm; ALE: 0.06 mm; PME: 0.125 mm; PLE: 0.13 mm. Eye ratio: AME/ALE 1: 0.35; AME/PME 1: 0.74; AME/PLE 1: 0.76.

**Variation**

Apart from minor differences in size and in relative length of legs little variation noted.

**Female**

Unknown.

**Etymology**

The name refers to the range of the species, the Kimberley Division.

**Distribution and Habits**

Central Kimberley Division, northwestern Australia (Figure 29). Habits unknown, because collecting circumstances highly untypical.

**Relationships**

T. kimberleyana is a systematically isolated species that has its nearest relatives presumably in the nanutarrae group.

**Tamopsis circumvidens group**

**Tamopsis circumvidens Baehr and Baehr**


**New Material Examined**

**Australia:** Western Australia: 1 d, 40 km N. of Johnston Lakes (S. of Coolgardie), 1 Jan. 1977, A.M. Douglas, M.J. Douglas (ABFC) (WAM 96/185).

**Remarks**

This is perhaps a mallee species that ranges from southern central Western Australia into northwestern Victoria. The new record is not far from the known localities in Western Australia.

**Tamopsis tropica group**

**Tamopsis tropica Baehr and Baehr**


**New Material Examined**

**Australia:** Northern Territory: 2 d, 1 9, Litchfield Park-Aida Ck, 4 Sept. 1992, Wells & Webber (MNTD).

**Remarks**

The new records corroborate the presence of *T. tropica* in the northern part of the Northern Territory.

**Tamopsis ediacarae Baehr and Baehr**

Figures 23, 24, 29

*Tamopsis ediacarae* Baehr and Baehr, 1988: 15.

**New Material Examined**

Diagnosis
Medium-sized, moderately long-legged species, further characterized by PLS shorter than abdomen, MTA with membranous area and a scopula-like organ within, and LA with characteristic sharp, medially conspicuously angulate edge.

Description

Male (SAMA N1994210)
Measurements: Length: 4.40 mm; cephalothorax length: 1.72 mm; width: 1.75 mm; abdomen length: 2.45 mm; width: 1.92 mm. Legs: I: 23.24 mm; II: 22.02 mm; III: 5.98 mm; IV: 19.73 mm. Ratio: 1: 0.95: 0.26: 0.85. Ratio LB/LL: 0.19. PLS length: 2.32 mm; bs: 0.48 mm; ts: 1.84 mm. Length ratio PLS/abd: 0.95. Diameter of eyes: AME: 0.195 mm; ALE: 0.08 mm; PME: 0.15 mm; PLE: 0.15 mm. Eye ratio: AME/ALE 1: 0.41; AME/PME 1: 0.77; AME/PLE 1: 0.77.

Colour: Cephalothorax light yellow; border and radial stripes mottled with dark, eye area dark, clypeus largely yellow, chelicerae at base narrowly dark. Sternum light yellow. Abdomen in anterior half with a dark median longitudinal stripe, laterally rather regularly mottled with dark, posterior half with several light and dark transverse bars. Ventral side light. Legs and PLS yellow brown, legs distinctly annulate; PLS with two conspicuous dark rings.

Cephalothorax: About circular. Carapace with median post-foveal depression. Eye area markedly raised, clypeus visible from above, almost as high as eye area. AME by far the largest, PME as large as PLE. Distance AME/AME 0.11 mm, slightly > than 1/2 diameter of AME, distance AME/ALE 0.06 mm, slightly < than diameter of ALE. Distance PME/PME 0.5 mm, c. 1/3 of diameter of PME, distance PME/PLE 0.11 mm, slightly > 2/3 of diameter of PLE. Chelicerae c. 1.8 x as long as wide. Sternum pentagonal, with some hairs.

Abdomen: Moderately elongate, slightly longer than wide, wider than cephalothorax. Surface covered with short hairs, upper surface also rather densely covered with brown bristles, lateral and ventral surfaces covered with elongate, light hairs. Dorsally with five pairs of circular DMP, VMP in a narrow v-shaped arrangement. PLS slightly shorter than abdomen, ts rather elongate.

Legs: Very elongate, measurements see above.

Palpus: MTA strongly contorted. Apex with a large membranous area and a scopula-like organ within. Ventral border with strong, elongate roof-like hook. Lateral rim elongate, projecting beyond the hook. LA elongate and contorted, with very sharp, medially characteristically triangular edge. Apex with one fairly deep u-shaped incision (Figures 23, 24).
New species and records of Hersiliidae

**Variation**
Apart from usual sexual variation and some differences in body size little variation noted.

**Remarks**
This species was known from a single female only. The new records include some males collected together with a female which enables us to describe the unknown male and to distinguish it from related species. Therefore, we include a revised diagnosis and the full description of the male.

The new records included, this species is now known from a restricted area in eastern inland South Australia (Figure 29). The species is closely related to *T. petricola* Baehr and Baehr from southern inland Queensland, but the male palpus differs in the sharply angulate median edge of LA and the deeply incised apex of LA, and the female vulva differs by the characteristic basal coiling of the intraductory ducts.

**Tamopsis gracilis** Baehr and Baehr

*Figure 29*
*Tamopsis gracilis* Baehr and Baehr, 1993a: 379.

**New Material Examined**
Australia: Western Australia: 1 ♂, Mt Elvire Stn site ME 8, dry pitfall traps 29°26'S, 119°34'E, 13-17 Sept. 1994, coll. A. Burbridge et al. (WAM 96/196).

**Remarks**
This small species was known so far only from the Hamersley Ranges. The new record considerably enlarges the recorded range to the south demonstrating that this is perhaps an Western Australian inland species (Figure 29). The specimen is very small (c. 2.8 mm long), extremely long-legged like the holotype, but differing from the holotype it is fully coloured and has a contrasting coloured abdomen with conspicuous black median stripe and lateral margins, whereas the white colour between is arranged into two more or less regular longitudinal stripes.

**Tamopsis leichhardtiana** Baehr and Baehr

*Figure 28*
*Tamopsis leichhardtiana* Baehr and Baehr, 1987: 382; Baehr and Baehr, 1993a: 379.

**New Material Examined**
Australia: Northern Territory: 1 ♂, 1 immat. ♂, Darwin, Stuart Park Vine Forest, April 1993, Webber (MNTD); 1 ♂, Katherine Gorge NP, Edith Falls, sweeping grass, 6 Dec. 1980, M. B. Malipatil & L. Archibald (MNTD).

**Remarks**
This species was recorded only from the type locality in central southern Western Australia. The new record enlarges the known range of this species into the southwestern part of South Australia (Figure 29). The name of this species already indicates that it is apparently a mallee inhabiting species, like several other species that are widely distributed through the semi-arid mallee belt of southern Australia from southwestern Australia into western Victoria or even into southern or inland New South Wales.

**Tamopsis pseudocircumvidens** Baehr and Baehr

*Figure 27*
*Tamopsis pseudocircumvidens* Baehr and Baehr, 1987: 381.

**New Material Examined**

**Remarks**
The new records fill the apparent distribution gap between northwestern Queensland and northern Western Australia. This species seems to range through the entire tropical belt of northern Australia (Figure 28).

In colour pattern both specimens resemble the one mentioned in Baehr and Baehr (1993a) from Western Australia.

**Tamopsis mallee** Baehr and Baehr

*Figure 29*
*Tamopsis mallee* Baehr and Baehr, 1989: 316.

**New Material Examined**

**Remarks**
This species was recorded only from the type locality in central southern Western Australia. The new record enlarges the known range of this species into the southwestern part of South Australia (Figure 29). The name of this species already indicates that it is apparently a mallee inhabiting species, like several other species that are widely distributed through the semi-arid mallee belt of southern Australia from southwestern Australia into western Victoria or even into southern or inland New South Wales.
Remarks

Tamopsis pseudocircumvindex was so far known only from the female holotype collected in southwestern Australia. In the description of T. marri (Baehr and Baehr, 1989) the decision whether it is conspecific with T. pseudocircumvindex, or not, was postponed until males would be known. Now, we have samples including males and females from South Australia, the male palpus of which is similar to that of T. marri, whereas the female vulva is alike that of T. pseudocircumvindex. Hence, we now feel sure that both names should be synonymized. The species is now recorded from southern New South Wales, southern central South Australia, southern Northern Territory, and southern Western Australia (Figure 27).

Tamopsis warialdae sp. nov.

Figures 25, 26, 28

Material Examined

Holotype


Diagnosis

Medium-sized, moderately long-legged species, further characterized by PLS shorter than abdomen, epigyne with elongate lateral RS and not circular apex of median RS.

Description

Female holotype

Measurements: Length: 3.30 mm; cephalothorax length: 1.55 mm; width: 1.48 mm; abdomen length: 1.68 mm; width: 1.80 mm. Legs: I: 11.34 mm; II: 11.44 mm; III: 4.15 mm; IV: 10.88 mm. Ratio: I: 1.01: 0.37: 0.96. Ratio LB/LL: 0.29. PLS length: 1.50 mm; bS: 0.42 mm; tS: 1.08 mm. Length ratio PLS/abd: 0.89. Diameter of eyes: AME: 0.15 mm; ALE: 0.065 mm; PME: 0.15 mm; PLE: 0.15 mm. Eye ratio: AME/AME 1: 0.43; AME/PME 1: 1; AME/PLE 1: 1.

Colour: Cephalothorax light yellow; border and radial stripes largely mottled with dark, eye area dark though laterally of eyes light, clypeus light but laterally dark and with a dark median stripe, chelicerae largely dark. Sternum light yellow. Abdomen in anterior half with a dark median longitudinal stripe, laterally densely mottled with dark, posterior third with several light and dark transverse bars. Ventral side light. Legs and PLS yellow brown, legs conspicuously annulate; PLS with two dark rings, base of PLS laterally with narrow dark border.

Cephalothorax: About circular. Carapace with median post-foveal depression. Eye area strongly raised, clypeus visible from above, c. as high as eye area. AME as large as PME and PLE. Distance AME/AME 0.105 mm, c. 2/3 of diameter of AME, distance AME/ALE 0.06 mm, slightly < than diameter of ALE. Distance PME/PME 0.045 mm, slightly < than 1/3 of diameter of PME, distance PME/PLE 0.11 mm, c. as wide as 2/3 of diameter of PLE. Chelicerae c. 1.8 x as long as wide. Sternum pentagonal, with some hairs.

Abdomen: Short and wide, rather triagonal, wider than cephalothorax. Surface covered with short hairs, upper surface also rather densely covered with brown bristles, lateral and ventral surfaces covered with elongate, light hairs. Dorsally with five pairs of circular DMP. VMP in a narrow v-shaped arrangement. PLS shorter than abdomen, IS rather short.

Legs: Moderately elongate, measurements see above.

Epigyne: Laterally with slit-shaped pocket, medially between RS with an inconspicuous sclerotized bar (Figure 25).
New species and records of Hersiliidae

Figure 27  Distribution of *Hersilia bifurcata* sp. nov.: ○; *H. longbottomi* sp. nov.: ◊; *H. tenuifurcata* sp. nov.: △; *H. wellsweberae* sp. nov.: □; *Tamopsis hirsti* sp. nov.: ■; *T. gibbosa* Baehr and Baehr: ♦; *T. pseudocircumoides* Baehr and Baehr: ●.

Figure 28  Distribution of *Tamopsis facialis* Baehr and Baehr: ●; *T. minor* sp. nov.: ■; *T. transiens* Baehr and Baehr: ♦; *T. leichardti* Baehr and Baehr: ▲; *T. warialdae* sp. nov.: ▼.
Vulva: With two RS, the lateral RS longer than the median RS, both rather elongate. Basal bulbus and basal two thirds of lateral RS glandular. One introductory duct present that ends medially and backwards (Figure 26).

Male
Unknown.

Etymology
The name refers to the type locality.

Distribution and Habits
Northeastern New South Wales, west of Great Dividing Range (Figure 28), known only from the type locality. Habits and collecting circumstances unknown.

Relationships
According to shape of epigyne and vulva, *T. varioidae* is next related to *T. ediacarac*, *T. pseudocircularis*, and *T. jorgi*, but is distinguished from all of these by the longer lateral RS and the less circular apex of the median RS.

Identification
For identification of the new species, of the newly described, hitherto unknown sexes of known species, and of those species that have changed their taxonomic status, the key to the Australian species of *Tamopsis* in the fourth supplement (Baehr and Baehr, 1993a) and the supplementary parts of this key in Baehr & Baehr (1995) should be altered as follows:

13. MTA with wide incision. LA sinuate (Baehr and Baehr, 1987 Figure 21). Southeastern Queensland, eastern New South Wales. .......... queenslandica Baehr and Baehr

13a. LA near apex without sharp bend, apex not deeply incised (Baehr and Baehr, 1992 Figures 4–6). Southwestern Australia, southernmost South Australia. ..................... recevesbyana Baehr and Baehr

15. LA at apex not incised (Baehr and Baehr, 1987 Figure 17). Central Queensland. ..................... centralis Baehr and Baehr
New species and records of Hersiliidae

La at apex incised (Baehr and Baehr, 1993 Figures 7, 8; Figures 17, 18). Western Australia, southern part of South Australia, southern New South Wales............... 15a

15a. Face with conspicuous white spots. PLS markedly shorter than abdomen. Seminal duct in m palpus regularly shaped, base of LA bulbous, apex of LA wider and less deeply notched (Baehr and Baehr, 1993 Figures 7, 8). Western Australia south of Pilbara region, southern part of South Australia, southern New South Wales. ................................................................. *facialis* Baehr and Baehr

Face without or with less conspicuous white spots. PLS about as long as abdomen. Seminal duct in m palpus irregularly curved, base of LA less bulbous, apex of LA narrower and more deeply notched (Figures 17, 18). Kimberley Division, northwestern Australia ................................. *minor* sp. nov.

17. Apex of embolus hidden in LA. Apex of MTA with a peculiar projecting process within, without a hooked process on lateral rim (Baehr and Baehr, 1989 Figures 1, 2; Baehr and Baehr, 1992 Figures 9-11; Figures 21, 22). ........................................ 18

Apex of embolus freely projecting beyond MTA. Apex of MTA without a projecting process within, but with a hooked process on lateral rim (Baehr and Baehr, 1987 Figures 27, 29) .................................................. 19

18. MTA with large hook-shaped process within membranous area (Figures 21, 22). Kimberley Division, northwestern Australia ................................. *kimberleyana* sp. nov.

MTA without such large hook-shaped process within membranous area (Baehr and Baehr, 1989 Figures 1, 2; Baehr and Baehr, 1992 Figures 9-11). Distribution different............. 18a

18a. Apical process of MTA shorter. Lateral part of apex of LA not widened nor incised (Baehr and Baehr, 1989 Figures 1, 2). Northwestern Australia south of Great Sandy Desert ............ ................................................................. *mauritaniae* Baehr and Baehr

Apical process of MTA longer. Lateral part of apex of LA distinctly widened and incised (Baehr and Baehr, 1992 Figures 9-11). Southwestern Australia, southern central Australia, northwestern Victoria ................................. ................................................................. *transiens* Baehr and Baehr

27. LA with sharp edge that is conspicuously angulate in middle (Figures 23, 24). Eastern central South Australia ................................................................. *etiiacarae* Baehr and Baehr

LA without or with sharp edge, but in latter case edge not conspicuously angulate in middle (Baehr and Baehr, 1987 Figure 41; Baehr and Baehr, 1989 Figures 3, 4; Baehr and Baehr, 1995 Figures 4, 5) .................... 27a

27a. LA with a deep median and a narrow lateral incision (Baehr and Baehr, 1987 Figure 41e). Central western Australia south of Great Sandy Desert ................................. *occidentalis* Baehr and Baehr

LA without or with less deep median incision (Baehr and Baehr, 1989 Figure 4; Baehr and Baehr, 1995 Figures 4, 5) ........................................... 27aa

27aa. LA without median incision, lateral incision very small (Baehr and Baehr, 1995 Figure 5b); apex of MTA very elongate, strongly hook-like process also very elongate, dorsally with rims, lateral rim of apex high and elongate, projecting beyond the hook-like process. Southeastern inland Queensland ........................................ *petricola* Baehr and Baehr

LA with less deep median incision, lateral incision deep (Baehr and Baehr, 1989 Figure 3; Baehr and Baehr, 1995 Figure 4b, arrow) ................................. 27b

27b. Lateral incision of LA nearly circular, both processes rounded (Baehr and Baehr, 1989 Figure 3); lateral rim high, lamelliform, but posteriorly not so high as the hook. Southwestern Australia, southern Northern Territory, central South Australia, southwestern New South Wales ........................................ .... *pseudocircumvidens* Baehr and Baehr

Lateral incision of LA u-shaped, with a rounded and a sharp process (Baehr and Baehr, 1995 Figure 4b, arrow); lateral rim of MTA high, lamelliform, posteriorly as high as the hook (Baehr and Baehr, 1995 Figure 4b). Central Western Australia, Gibson Desert ........................................ *joagi* Baehr and Baehr

35. cancel 35, continue at 36

39. Dorsal RS well divided, as long as ventral RS, or longer (Baehr and Baehr, 1987 Figure 22; Baehr and Baehr, 1995 Figures 11, 12). Southeastern Queensland, eastern New South Wales, central Northern Territory ... 40

Dorsal RS indistinctly divided, about half as long as ventral RS (Baehr and Baehr, 1987 Figure 18; Baehr and Baehr, 1992 Figures 7, 8). Southwestern Australia, southern South Australia ........................................ *reevesbyana* Baehr and Baehr

51. Epigyne with large plate bearing conspicuous
ridges medially of pocket (Baehr and Baehr, 1993 Figures 17, 18; Figures 19, 20). Western Australia, southern part of South Australia, southern New South Wales .................. 51

Epigyne without such plate (Baehr and Baehr, 1987 Figure 26). Eastern New South Wales ... .......................... brevipes Baehr and Baehr

51a. Larger species, length >5.5 mm. Abdomen conspicuously triangular. PLS considerably shorter than abdomen. Lateral parts of epigyne more curved anteriorly (Baehr and Baehr, 1993 Figures 17, 18). Western Australia south of Pilbara region, southern part of South Australia, southern New South Wales .................. facialis Baehr and Baehr

Smaller species, length <4.5 mm. Abdomen rather circular. PLS as long as or longer than abdomen. Lateral parts of epigyne less curved anteriorly (Figures 19, 20). Kimberley Division, northwestern Australia .................. minor sp. nov.

54. Apical section of inner RS conspicuously circular, with narrow duct (Baehr and Baehr, 1987 Figures 34–36; Baehr and Baehr, 1988 Figures 2, 3; Baehr and Baehr, 1989 Figures 5, 6; Baehr and Baehr, 1993a Figures 23, 24; Baehr and Baehr, 1995 Figure 4) .................. 55

Apical section of inner RS not conspicuously circular, not separated by a narrow duct (Baehr and Baehr, 1987 Figures 32, 38, 40, 42, 44; Figure 26) .................. 61

55. Vulva very wide and with a broad, sclerotized bridge. Lateral RS nearly as long as median RS (Baehr and Baehr, 1987 Figure 34; Baehr and Baehr, 1988 Figure 3; Baehr and Baehr, 1989 Figures 5, 6) .................. 56

Vulva narrower, with a narrow sclerotized bridge. Lateral RS considerably smaller than median RS (Baehr and Baehr, 1987 Figures 35, 36; Baehr and Baehr, 1988 Figure 2; Baehr and Baehr, 1995 Figures 23, 24) .................. 57

56. Bridge of epigyne located rather posteriorly between RS (Baehr and Baehr, 1987 Figure 34; Baehr and Baehr, 1989 Figures 5, 6). Southwestern Australia, central South Australia, southern Northern Territory, southwestern New South Wales .................. pseudocircumduexus Baehr and Baehr

Bridge of epigyne located anteriorly at apex of RS (Baehr and Baehr, 1988 Figure 3). Eastern central South Australia .................. edilacae Baehr and Baehr

57. = 58 etc.

61. Small or medium sized species, length < 4 mm (Baehr and Baehr, 1987 Figure 4; Figure 26).

61a. AME much larger than PME and PLE. Lateral RS shorter than median RS (Baehr and Baehr, 1987 Figure 4). Northern Queensland, northern part of Northern Territory .................. tropica Baehr and Baehr

AME not larger than PME and PLE. Lateral RS considerably longer than median RS (Figure 26). Northeastern New South Wales .................. warialdae sp. nov.

DISCUSSION

Biology

Even after several years of intensive collecting work, still rather little is known about the biology of the Australian Hersiliidae. Although a number of observations on collecting circumstances have been reported, most of these seems more or less atypical. And almost no new observations have been recorded about hunting and prey, and mating and propagation. In spite of the rather large numbers of additionally captured specimens, we think that many of these were collected more or less accidentally and in atypical situations. So, the hersiliids examined for the present contribution were captured: “on building”, “on Euc. with loose bark”, “trunks of banksia”, “sand dune, along dog fence”, “on Mulga Tree”, “on white eucalypt trunk”, “on fuel tank”, “on white-barked river gum”, “on river gum”, “on white bark eucalypt”, “on rocks”, “at M.V. light”, “at Eucalyptus hillii at night”, “ex eucalypt in garden”, “on mallee nr creek”, “off buggy”, “on diesel fuel tank”, “on walnut tree-trunk”, “on Melaleuca”, “drowned in swimming pool”, “on shrub”, at “edge of car park”, “on trailer while camping”, in “dry pitfall traps”, “sweeping grass”, and “along dog fence”. Of these records, rather few seem to represent observations of typical habits, but most are rather atypical or even highly surprising. However, as already suspected in the discussion of our fourth supplement (Baehr and Baehr, 1993a), sampling records of the high-eyed species (e.g. for T. pertheiisis, T. occidentalis, T. fickerli, T. fitzroyeiisis) commonly refer to their occurrence on eucalypt bark. These observations well agree with our own experience and generally seem to be more reasonable than many of the records for the low-eyed species, some of which are rather strange and probably do not give a real picture of the true occurrence.
New species and records of Hersiliidae

Distribution

The discovery of as many as four new species of the genus Hersilia in Australia is surprising, the more, as all species belong to a very distinctive species-group and are closely related. According to the highly evolved structure of the embolar apparatus, this group seems to be a highly apomorphic one that is more derived in the characters of the male palp than any species known from New Guinea. So, it may be a genuine Australian group, the origin of which is still obscure.

All new species are recorded from far Northern Territory or from the Kimberley Division in far northwestern Australia. Surprisingly enough, thus far no Hersilia species was recorded from northern Queensland. It is yet uncertain whether this apparent absence is due to inadequate sampling in northern Queensland, whether it does reflect the real absence of species of the genus Hersilia in that part of tropical Australia. Anyway, at the present state of knowledge, the genus Hersilia seems to be a completely tropical element in the Australian hersiliid fauna that may be restricted to far northern and northwestern Australia.

With respect to the genus Tamopsis, the common sampling of males and females of several species enables us to settle certain taxonomic and chorological problems. The discovery of a species of an additional species-group (kimberleyana-group) demonstrates that the systematic diversity of Hersiliidae in Australia is by no means fully recorded.

In many species, range extensions are recorded, and in most of these, the recorded ranges were enlarged to cover the semiarid belt across southern Australia, or range extensions in northeastern Australia or across the arid centre were established.

In particular the distribution pattern across semiarid southern Australia seems to be very common, and species showing this pattern commonly seem to inhabit the mallee belt and actually live on mallee eucalypts. Probably, further sampling will demonstrate that several species have wider ranges than expected which means that overlapping of ranges of different species will be more commonly recorded in future. Even so, the number of still undiscovered species does not seem to be dropping significantly, and the question becomes increasingly important, how so many sympatric or even syntopic species apparently having a rather similar way of life could manage to live together. We suspect that habits and way of life in general might be more different than we imagined thus far. Hence, in future, even more attention should be payed to sampling of information about ecological and ethological features.

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REFERENCES


**Checklist of Australian Hersiliids**

For the benefit of the user a checklist of all Australian hersiliid species and of the species groups of the genus *Tamopsis* is added that includes information about the presently known ranges.

**Genus *Hersilia***

- *H. anstraliensis* Baehr & Baehr, 1987  
  n.NT
- *H. bifurcata* sp. nov.  
  n.NT
- *H. mainac* Baehr & Baehr, 1995  
  n.WA
- *H. mimbi* Baehr & Baehr, 1993  
  n.WA
- *H. tenifurcata* sp. nov.  
  n.WA
- *H. wellsibbaecrae* sp. nov.  
  n.NT

**Genus *Tamopsis***

- *T. amplithorax* Baehr & Baehr, 1987  
  s.WA
- *T. depressa* Baehr & Baehr, 1987  
  nc.NT, cw.WA
- *T. platycephala* Baehr & Baehr, 1987  
  se.QLD
- *T. braclycauda* Baehr & Baehr, 1987  
  e.QLD, e.NSW
- *T. tzveedensis* Baehr & Baehr, 1987  
  ne.NSW
- *T. eucalypti* (Rainbow, 1900)  
  SA, VIC, ACT, e.NSW, e.QL.D
- *T. facialis* Baehr & Baehr, 1993  
  s.NSW
- *T. daviesae* group
  - *T. daviesae* Baehr & Baehr, 1987  
    ne.QL.D
- *T. brevipes* Baehr & Baehr, 1987  
  e.NSW
- *T. centralis* Baehr & Baehr, 1987  
  c.QL.D
- *T. costae* Baehr & Baehr, 1987  
  sc.QL.D
- *T. darlingtoniana* Baehr & Baehr, 1987  
  sw.WA
- *T. gibbosa* Baehr & Baehr, 1993  
  sw.SA, sw.WA
- *T. harveyi* Baehr & Baehr, 1993  
  c.NT
- *T. lirsi* sp. nov.  
  ec.SA

- *T. kochi* Baehr & Baehr, 1987  
  c.NSW, se.WA
- *T. mainac* Baehr & Baehr, 1993  
  sw.WA
- *T. minor* sp. nov.  
  n.WA
- *T. pankaii* Baehr & Baehr, 1993  
  sc.WA
- *T. queenslandica* Baehr & Baehr, 1987  
  c.QL.D, c.NSW, c.WA
- *T. reyesci* Baehr & Baehr, 1987  
  se.QL.D, s.SA
- *T. derec Sửbaa* Baehr & Baehr, 1987  
  s.SA, sw.WA
- *T. = distingueda* Baehr & Baehr, 1992  
  nw.VIC, sw.WA
- *T. uvirii* Baehr & Baehr, 1995  
  n.WA
- *T. amblenusseus group*
  - *T. amblenusseus* Baehr & Baehr, 1987  
    n.QL.D, n.NT
- *T. circumvidens group*
  - *T. circumvidens* Baehr & Baehr, 1987  
    mw.VIC, s.WA
- *T. nanutarrae group*
  - *T. nanutarrae* Baehr & Baehr, 1989  
    cw.WA
- *T. transiens* Baehr & Baehr, 1992  
  nw.VIC, sw.NT, cs.WA
- *T. kimberleyana group*
  - *T. kimberleyana* sp. nov.  
    n.WA
- *T. tropica group*
  - *T. ediacarae* Baehr & Baehr, 1988  
    ec.SA
  - *T. fickerti* (L. Koch, 1876)  
    s.SA, e.VIC, NSW, se.QL.D
  - *T. fitzroyensis* Baehr & Baehr, 1987  
    n.QL.D, n.WA
  - *T. forestae* Baehr & Baehr, 1988  
    n.QL.D
  - *T. gracilis* Baehr & Baehr, 1993  
    c.WA
  - *T. jorgi* Baehr & Baehr, 1993  
    c.WA
  - *T. leichhardtia* Baehr & Baehr, 1987  
    nc.QL.D, n.NT, cw.WA
  - *T. longbotlomi* Baehr & Baehr, 1993  
    n.NT
  - *T. malle* Baehr & Baehr, 1989  
    sw.SA, sc.WA
  - *T. occidentalis* Baehr & Baehr, 1987  
    cw.WA
  - *T. perlensis* Baehr & Baehr, 1987  
    c.WA
  - *T. petricola* Baehr & Baehr, 1995  
    cs.QL.D
  - *T. pseudocircumvidens* Baehr & Baehr, 1987  
    s.NSW, ec.SA, s.WA, s.NT
  - *T. = marri* Baehr & Baehr, 1989  
    n.WA
  - *T. rossi* Baehr & Baehr, 1987  
    s.WA
  - *T. trionyx* Baehr & Baehr, 1987  
    s.QL.D
  - *T. tropica* Baehr & Baehr, 1987  
    n.QL.D, n.NT
  - *T. varriellae* sp. nov.  
    ne.NSW

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The Cervantes egg: an early Malagasy tourist to Australia

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Abstract - A large fossil bird's egg discovered near Cervantes in Western Australia is identified as belonging to \textit{Aepyornis maximus} by its size and eggshell structure. It is the second such egg found in Western Australian Holocene beach dune deposits. Radiocarbon dating of the specimen gives an age of about 2000 years. By comparison with other known rafting events, we suggest that this egg and the Scott River \textit{Aepyornis} egg both drifted across on oceanic currents from Madagascar and were not brought to Australia by human intervention.

INTRODUCTION

A large fossil bird's egg (Figure 1) was discovered by three primary school students about 7 km north of the town of Cervantes, in Western Australia, in late 1992. It represents the second such discovery of a very large fossil bird egg from the dune deposits of southern Western Australia, the first being found by Mr Vic Roberts, then ten years old, near the mouth of the Scott River, near Augusta in 1930. Well-known naturalist Harry Butler saw this egg in a farmhouse in Nannup in 1962 and informed the Western Australian Museum, which now has the egg (Figure 2) on a permanent loan from Roberts.

The Cervantes egg was found exposed in sand dunes about 300 m inland from the coast. Mory (1994) referred to this egg as being found in Holocene dunes overlying lagoon deposits, suggesting that the sediments containing the egg were probably less than 3000 years in age. Radiocarbon dating of the Cervantes egg as about 2000 years (see below) fits in well with this suggested geomorphological age of the dune deposits.

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The Cervantes find was announced to the public through an article in \textit{The Sunday Times} newspaper on the 21st March 1993 and subsequently received an enormous amount of media coverage locally, nationally and even internationally. Despite initial disputes over the ownership and attempts by the finders to auction or sell the egg, the Western Australian Government eventually made a ruling that under the Lands Act the specimen, which was found on Crown Reserve Land, actually belonged to the Crown. An \textit{ex gratia} payment of $25,000 was later made to the families involved as a goodwill payment. The legal wrangle surrounding the egg's ownership was thus important in precipitating the first draft legislation pertaining to fossils and their ownership for the State of Western Australia.

The Cervantes egg is now a registered specimen in the Western Australian Museum palaeontological collections, as WAM 93.9.1. Preliminary observations on the egg were first published by Long (1993).

IDENTIFICATION OF THE CERVANTES AND SCOTT RIVER EGGS

The Cervantes egg measures 31.7 cm in length, being significantly larger than the Scott River egg at 27.6 cm long. Both the Cervantes and Scott River eggs appear to belong to the extinct flightless bird \textit{Aepyornis maximus}, which lived in Madagascar until as little as 400 years ago (Figure 3). This bird reached gigantic sizes of up to 2.5 m tall and would have weighed more than half a tonne.

The Cervantes eggshell is quite thick, ranging from 3.05 to 3.45 mm where it could be measured, and this compares well to the measurements of the Madagascar Elephant Bird, \textit{Aepyornis}. The shell structure is best viewed in radial thin sections (Figure 4) and is of an ornithoid-ratite morphotype (Hirsch and Packard 1987). There are two pronounced shell layers, the well-structured mammillary layer and the continuous spongy layer with an abrupt change of the structure between
them. In the case of Aepyornis, a third outer layer is present.

The external layer is relatively thick, more so than that found in the only other ornithoid ratite, the Ostrich (Struthio). The continuous inner layer is similar to that in both the Ostrich and the Emu (Dromaius). This layer has pronounced, horizontal growth lines and otherwise looks structureless in comparison to the mammillary layer.

The mammillary layer is almost one third of the eggshell thickness. It has a radial, wedge-like arrangement of the tubular crystalline material, and on the base of the large mammillae a particularly fine ultrastructure is visible.

The pore canal observed in the Cervantes eggshell is single and non-branching. Aepyornis has single or branched pore canals. The pore pattern on the surface of the eggshell (Figure 5), opening into long, narrow slits is very reminiscent of Aepyornis, and not of other ratites. Just as in Aepyornis, the pores of the Cervantes egg opened either singly or multiply in the long pore slits. The Cervantes egg is in the size range and of similar shape to known Aepyornis eggs.

The Scott River egg has a similar eggshell texture to that of the Cervantes egg, but has been sand blasted along one side, creating a smooth, polished, but slightly pitted surface.

A comparison to the eggs of large birds known from Australia, the dromornithids, reveals distinct differences, namely in the structure of the surface areas in which pore canals open. In Genyornis, where this can be well observed, these pore slits are markedly curved. In the Cervantes egg the slits are straight. The surface of the Cervantes egg is smooth as in Genyornis, where shell thickness is much less (with an average of material we measured being about 1.15 mm) and different from eggs of the largest dromornithid known with a thickness of 4.07 mm, which had a crenulated, rough surface (Williams and Rich 1992, 1996).

**DATING OF THE CERVANTES EGG**

The loose material found inside the egg was selected for dating on the basis that this sample was best protected from contamination. The material was extracted using a dentist drill in the clean laboratory at ANSTO.

Organic samples to be analysed by Accelerator Mass Spectrometry (AMS) needed to be purified and transformed into graphite target for the ion source. First CO was obtained from two samples, one of 40 mg and one of 80 mg by hydrolysis in hydrochloric acid under vacuum. The resulting gas was graphitised onto an iron catalyst using zinc for the initial reduction to carbon monoxide. The graphite/iron mixtures were finally pressed into cathodes and loaded into the iron source on the ANTARES AMS spectrometer (Tuniz et al. in press).

The procedure for the analysis of the $^{14}C/^{12}C$ isotopic ratio is here briefly described. Negative carbon ions are produced in the sputter ion source and, after low-energy mass analysis, they are injected into the tandem accelerator. High precision AMS measurements are carried out by rapid sequential injection of the isotopes $^{14}C$ and $^{12}C$ negative ions are attracted to the positive voltage at the terminal and thereby accelerated to energies of 5.2 MeV at which point they pass through a carbon foil and are stripped of some of their electrons. Multi-charged positive ions are then further accelerated by the same positive voltage on the terminal. The isotopic ratio of $^{14}C/^{12}C$ is derived from the $^{14}C$ counting rate in the detector and the beam current of the stable isotope. Figure 6 shows the plot of data upon which the date is based.

The conventional radiocarbon age for the Cervantes egg is 1928 +/-73 yr BP, which corresponds to a calibrated age range of 12-187 yr AD (correction for natural isotopic fractionation was performed by assuming $\delta^{13}C = -14$ per mil (Berger 1975)). Conventional radiocarbon ages as
The Cervantes egg

reported in years BP (before present, where present is 1950 AD) and are calculated using the "Libby" half-life of 5568 years and the assumption that the production of $^{14}$C has been constant. The differences between conventional radiocarbon ages and calibrated ages has been determined with high precision for most of the Holocene by radiocarbon measurements on tree ring samples, which are independently dated by dendrochronology. Part of this difference derives from the use of conventional half-life, which is known to be 3% too small. The remaining difference derives from secular variations of $^{14}$C production rate in the atmosphere for geo- and helio-magnetic effects and global variations in the parameters of the carbon cycle.

Shell fragments (>10 g) from Aepyornis eggs found in the sand dunes of Madagascar, have been dated previously using conventional radiocarbon methods, yielding ages which span the period 850 to 7500 yr BP (Berger 1975; Long et al. 1983).

SUPPORT FOR THE DRIFTING EGG HYPOTHESIS

The discovery of the Scott River egg caused quite a stir. Doubt was immediately cast on its authenticity. After all, how could a large egg float across the Indian Ocean and be washed up on a beach intact? Despite this incredible scenario, the identification of the egg as an Aepyornis, based on its surface texture, microstructure and overall size, appears most likely. Williams and Rich (1996) cast doubt on its identification as being from an
Aepiornis, yet the study of the second egg, from Cervantes, confirms its identity as also Aepiornis.

The discovery of the second Australian Aepiornis egg, from Cervantes, lends support to the drifting egg hypothesis. However, most convincing evidence comes from the recovery of two fresh King Penguin (Aptenodytes patagonicus) eggs on Western Australian beaches, which must have come from one of the subantarctic islands such as the Kerguelen Islands, some 2000 km away from Australia.

The first of the penguin eggs was found about 2 miles south of Augusta, close to the site of the original Scott River Aepiornis egg, on January 10th 1974. It was found by three beach fishermen who plucked it at the high water mark, examined it and threw it away behind the first sand dunes. On January 12th 1974 Geoff Lodge met with one of the fishermen, went to the site and after an hour’s search, and found the egg intact in the dune. When the egg was blown, it was found to contain an embryo quite advanced, without any odour of decay. As the egg laying season for these penguins is between late November and mid-April, the egg must have been transported in an advanced stage of incubation by the West Wind Drift, and was discovered almost immediately after reaching the Western Australian coast. The discovery of this egg and further details pertaining to it are described by Lodge (1976). The specimen is now held in the private collection of Mr G. Lodge at Boyup Brook, Western Australia.

A second egg of Aptenodytes patagonicus was found on Trigalow Beach, in Doubtful Bay Island near Bremer Bay on the southern coast of Western Australia in March 1991. This egg measures 11 cm long and is now registered in the ornithological collection of the Western Australian Museum as A24905. This egg is also intact and was covered with barnacles and algae, which were easily removed by the finder without damage to the shell before it was examined by museum scientists. The egg contained addled contents. The nearest living colonies for these penguins are Marion Island, the Crozets, the Kerguelen Islands and Heard Island (Figure 7). The most likely source, given the current patterns and proximity to Western Australia, would be the Kerguelen Islands.

Yet another egg, an Ostrich egg (Struthio camelus), was retrieved from a dredge in the Timor Sea in the early 1990s, just south of Timor, northwest of the Western Australian coastline. The egg was heavily weighed down with algae, so was not actually floating at the surface of the water, but suspended in mid-water according to its finder, who brought the egg into the Western Australian Museum. The egg was examined and identified as that of an Ostrich and returned to its finder by Ron Johnson of the Ornithology Department of the Western Australian Museum (R. Johnston, personal communication 1996).

And still another convincing piece of evidence favouring the rapid drifting hypothesis for the
Figure 4  Thin section (radial) of the egg shell of the Cervantes egg showing the three major layers (exactly the same in Aepyornis): arrows point to the boundary between the outer layer (top left only), the continuous layer (middle) and the mammillary layer. The dark vertical line indicated by the arrow is a faint indication of one of the pore canals (x30) (courtesy of K. Hirsch).

*Aepyornis* eggs comes from Betty Beach, near Manypeaks, Narrikup, Western Australia, where in 1980 a float was found that had originated in South Africa. The float had been released in 1977 as a part of a study of in-shore current movements. Thus, there is evidence supporting the transport of intact fragile material, such as eggs, over long oceanic distances.

One question raised with regard to long distance drift is the lack of marine encrustations that should occur on items such as eggs, if they had spent several months at sea. To this end, we observe that glass floats frequently wash up on Western Australian beaches that have barnacles on them and are soon sandblasted clean and polished. This process could have occurred to the *Aepyornis* eggs after they had reached shore, thus removing the trace of marine growth. Evidence for this is seen on the Scott River egg, which shows one surface highly polished from wind driven sand blasting.

Although long distance rafting is certainly a possibility, another exists, and that is one of short distance dispersal. During the 19th and 20th centuries it was not uncommon to find Elephant Bird eggs aboard ships sailing around the world. It
is possible that one or both of the eggs arrived near Australia aboard ship and with shipwreck ended up on Western Australian beaches, travelling only a short distance. We note that at the location of the Scott River egg, in the dunes near Augusta, there have been no records of early shipwrecks. Karl-Heinz Wrywoll, a specialist in Quaternary sedimentary deposits at the University of Western Australia, visited the site near Cervantes where the egg was found. He suggested that the Cervantes egg could easily have floated in on a quite recent storm surge as it was lying not far...

Figure 5  Surface structure of *Aepyornis* eggshell. Note the long slit-like structures into which the pores open. This type of structure is exactly what is seen in the Cervantes egg (x20).

Figure 6  Plot of data upon which the date of the Cervantes egg was based.
The Cervantes egg

Figure 7  Map showing the position of nearest living colonies of King Penguins, *Aptenodytes patagonicus*, whose eggs have also travelled by oceanic currents to end up on Western Australian beaches near Augusta (in 1976) and Bremer Bay (in 1991). Possible rafting route and sites where the two *Aepyornis* eggs were found are also indicated.

above the current high tide mark. The Holocene dunes in which the egg was buried contained no visible evidence of human activity, such as shipwreck artifacts or signs of Aboriginal influence, such as midden remains or tools. So, perhaps the Cervantes egg was a long distance marine tourist.

CONCLUSIONS

It appears that the egg recovered from near Cervantes by three primary school children in late 1992 is from the extinct Elephant Bird of Madagascar, *Aepyornis maximus*. The egg has been dated at about 2000 years of age and certainly could have reached the Western Australian coast by long distance rafting. It is still possible that it could have floated ashore from a shipwreck, but it is most likely an overseas tourist. Both in its form, macrostructure and microstructure it is more similar to *Aepyornis* than to any of the native giant land birds in the family Dromornithidae.

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Further records of plesiosaurian reptiles of Jurassic and Cretaceous age from Western Australia

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Abstract - Isolated vertebrae, limb bones and a tooth of plesiosaurian reptiles are described from the Middle Jurassic Colalura Sandstone, near Geraldton, Perth Basin; the Early Cretaceous Barrow Group (subsurface, near Exmouth), Carnarvon Basin; and the Late Cretaceous Molecap Greensand, near Dandaragan, Perth Basin. The first records of elasmosaurid plesiosaurians are described from Western Australia, including the oldest record of the group in Australia.

INTRODUCTION
Plesiosaurian reptiles were first discovered in Western Australia in the early 1940s, represented by isolated bones and teeth recovered from a test pit dug into the base of the Molecap Greensand, near the township of Dandaragan (Teichert and Matheson 1944). This material was briefly mentioned but not properly described nor identified beyond ordinal level.

Since then only a few bones have been mentioned in the literature or figured in popular field guides (Molnar 1991; Long 1993; McNamara et al. 1993). In 1992 and 1993 three partial skeletons of pliosaurids were recovered from the Early Cretaceous (Hauterivian-Barremian) Birdrong Sandstone exposed near Kalbarri, and these have recently been described by Cruickshank and Long (1997) as a new species, Leptocleidus clermi. These remains constitute the first associated partial skeletons of any Mesozoic reptiles from Western Australia. During the course of this work other isolated bones of plesiosaurians found from various sites in Western Australia were studied and are here summarised to complete the known record of the group for the State. Figure 1 shows a map indicating localities mentioned in this paper for all known Mesozoic reptile remains throughout Western Australia.

Specimens are reposited in the palaeontological collections of the Western Australian Museum (WAM) and in the Geology Department of the University of Western Australia (UWA).

MIDDLE JURASSIC COLALURA SANDSTONE
The Colalura Sandstone is exposed at Bringo railway cutting about 20 km to the east of Geraldton. Over the past three decades it has yielded scant vertebrate remains, including at least two dinosaur bones (Long 1992; Long and Molnar 1998) and the isolated bones of plesiosaurians described below. It conformably underlies the Bringo Shale and Newmarracarra Limestone, both of which contain marine invertebrate fossils of Middle Bajocian age (Playford et al. 1975).

Pectoral vertebra WAM 86.10.707
This specimen (Figures 2A–C, E; 3) which was previously figured by Long (1993: 53), has a very wide centrum, being 63 mm across by 42 mm high in the midline. It shows a large area where the articulation surface for the attachment of the pectoral rib was situated high up on the lateral faces of the centrum. The anterior zygapophysis is identified by the roughened area of bone on the anterior face of the neural arch (Figure 3A, a.z). The pectoral rib facet (Figure 3B, p.r) lies on both the neural arch and the centrum. It is very large, being of equivalent length as the midline height of the centrum. The neural arch is well-preserved (n.pr) with the base of the neural spine shown (Figure 3A, n.sp), enclosing the high, narrow opening for the spinal cord (n.c). There are widely spaced (c. 35 mm) but clearly visible subcentral foramina (Figure 3B, sc.f) on the ventral surface.

The wide proportions of the bone suggest it is
Figure 1  Map showing the location of Mesozoic reptile remains found in Western Australia.

most likely an elasmosaurid, and if so, constitutes the oldest record of the family in Australia. The only other elasmosaurid known from Australia is *Woolangasaurus glendowerensis* from the Early Cretaceous (Albian) of Queensland (Perrson 1960). The oldest elasmosaurids are from the Liassic (Lower Jurassic) of Europe (*Microcleidus*, Brown 1981).

Caudal vertebra UWA 36112

This is a very weakly preserved small vertebra (Figure 2F–J) showing the prominent haemal arches and well developed transverse processes (Figure 2F, G, I), and is probably a proximal caudal vertebra. It is 32 mm long, by 41 mm wide and 34 mm high in the midline. The neural arch was not firmly fused to the centrum as shown by the large attachment scars (Figure 2H), suggesting that the specimen came from a juvenile. The central faces are slightly concave and almost circular in form (Figure 2F, G), suggestive of typical plesiosaurid morphology without any specific family affiliation.

Figure 2  Plesiosaurian remains from the Middle Jurassic (Bajocian) Colapura Sandstone exposed at Bringo Cutting, near Geraldton. All natural size. A–C, E, ?elasmosaurid pectoral vertebra, WAM 86.10.707, in dorsal (A), anterior (B), ventral (C), posterior (D) and left lateral (E) views. F, plesiosaurian phalange bone in dorsal view, WAM 63.3.13. G–K, plesiosaurian proximal caudal vertebra, UWA 36112, in anterior (G), posterior (H), dorsal (I), ventral (J) and left lateral (K) views.
Figure 3  Sketch of possible elasmosaurid pectoral vertebra, WAM 86.10.707, showing main features, in anterior (A) and right lateral (B) views. a.z., anterior zygapophysis; n.c, neural canal; n.pr, neural process; n.sp, neural spine; p.r, pectoral rib attachment; sc.f, subcentral foramen.

It has well-developed posterior ventral processes for the chevron attachments (Figure 2f).

Plesiosaur phalange WAM 63.5.13
This bone (Figure 2F) was collected in 1963 by Mr Lindsay Peet, from the same site as the other two, at Bringo Cutting. It is typically plesiosaurian in having well rounded yet flattish cross-section through the shaft. It is 34 mm long by 17 mm wide at its proximal end, 12 mm high at the same end. It is distinguished from a dinosaur bone by its flatter shape. It gives no indication of familial placement within the Plesiosaurs.

EARLY CRETACEOUS (BERRIASIAN)
BARROW GROUP

Cervical vertebra WAM 95.12.1
One well-preserved specimen of a pliosaurid vertebra was found from a drill core (Macedon 3) by BHP Australia, and donated to the Western Australian Museum in 1995. The specimen (Figure 4D-G) is an anterior cervical with cervical ribs attached low on the lateral face of the centrum. It has clear foramina at the bases of the ribs indicating it had double headed ribs. The centrum measures 24 mm long, by 34 mm high in the midline, and 40 mm wide. Both anterior and posterior centrum faces are strongly concave. The bases for the neural arches are poorly defined remnants and the ribs are not fully fused to the centrum, suggesting it is from a subadult. The subcentral fossae are large, closey spaced and separated by a median ridge, a feature characteristic of plesiosaurians. We provisionally identify it as belonging to the genus *Leptocheirus* because it is very similar to material described as *Leptocheirus clemai* (Cruickshank and Long 1997).

LATE CRETACEOUS MOLECAP GREENSAND
Fossil vertebrates were first recorded from the Molecap Greensand by Teichert and Matheson.
Figure 5 Elasmosaurid vertebra, WAM 86.5.1, from the Molecap Greensand near Dandaragan, showing main features in anterior (A) and left lateral (B) views. a.z., anterior zygapophysis; n.c, neural canal; p.z., posterior zygapophysis; sc.f, subcentral foramen; tr.p, transverse process.

(1944) who reported the occurrence of ichthyosaurs and plesiosaurs, based on isolated vertebrae, rib fragments and teeth. The exact age of the Molecap Greensand vertebrates is in doubt because they occur at the base of the sequence in a phosphatic lag deposit which most likely includes reworked material. The shark tooth fauna associated with these reptile remains includes wide ranging forms from the Albian through to the end Cretaceous. A possible Cenomanian-Turonian age range for the Molecap Greensand is based on the overlying Gingin Chalk which contains the shark *Squalicorax kaupi*, of known Coniacian to Campanian age (M. Siverson, pers. comm. 1996).

**Dorsal vertebra WAM 86.5.1**

This specimen is the largest Mesozoic reptile bone so far found in the state, discovered by Mr Ivor Davies of Dandaragan in 1986 in a paddock ("fossil rise") near the township, where low outcrops of the Molecap Greensand are known to occur. It has been figured previously in McNamara

The specimen (Figures 4A–C, 11; 5, 6B) is a dorsal vertebra having a centrum measuring 96 mm long, the anterior face is 110 mm high in the midline by 117 mm wide. The neural arches are well ossified and firmly ossified to the centrum. The anterior and posterior zygapophyses (Figure 5, a.z, p.z) are well defined as are the wide transverse processes (Figure 5, tr.p), but the neural spine is missing. The cavity for the spinal cord (Figure 5, n.c) is wider than high. The centrum faces are weakly concave with a well-defined, slightly raised rim. The subcentral foramina (Figure 4H, 5, sc.f) are large, and closely situated to each other. The specimen resembles the dorsal vertebra of *Maiasaura haasti*, an elasmosaurid from the Late Cretaceous of New Zealand (Wiffen and Moisley 1986, figure 32) in having similar centrum proportions, but differs in the absence of the central raised swelling with median pit characteristic of that genus.

**Cervical vertebra UWA 22034**

This large bone (Figure 6A, C–E) is a posterior cervical possibly from an elasmosaurid due to its wide centrum which is markedly wider than its height and its length. The centrum measures 74 mm long, 102 mm wide and is 75 mm in midline height. The neural arch was well ossified to the centrum but only poorly defined remnants remain. There are large, moderately well-spaced apart subcentral foramina present (Figure 6D).

**Cervical vertebra UWA 22036**

This specimen (Figure 7) is a poorly preserved part of a centrum that nonetheless shows the elongated shape typical of the cervical vertebra of elasmosaurids. The centrum is 72 mm long by 65 mm wide, but the midline height cannot be accurately restored. The subcentral foramina (Figure 7B, sc.f) are large and closely situated to each other. The centrum faces are weakly concave with a median tuberosity in the centre on one face (Figure 7C, t). This appears to be an age related feature (Brown 1981).

**Plesiosaurian caudal vertebra UWA 22037**

This plesiosaurian caudal vertebra (Figure 6F, H,l) measures 20 mm long by 36 mm wide by 35 mm high in the midline of the centrum. It lacks neural arches but their attachment bases are clearly defined. The centra are deeply concave. It closely resembles the posterior caudal vertebrae of *Leptocheirus elegans* from the Early Cretaceous Birdrong Sandstone (Cruickshank and Long 1997).

**Tooth UWA 22041**

This isolated tooth (Figure 6G) is a well-preserved specimen showing numerous fine striations (about 14 on the lingual side) and has a large pulp cavity. The buccal side is much smoother. The shape is sigmoidal, recurved, being typical of elasmosaurid teeth (e.g., Brown 1981). It is 26 mm long and 8 mm broad across the base. Another specimen (WAM 79.8.10) from Cooks...
Plesiosaurian reptiles from Western Australia

Property at Dandaragan, is also a small piece of reptile tooth showing enamel and the pulp cavity yet we are not able to identify it as plesiosaurian, so mention it here only for the sake of recording it in the literature.

Pectoral rib, UWA 22038

There two fragments of thick, well-ossified ?plesiosaurian pectoral rib, hardly worthy of illustration, but are included here to complete the list of known material. One fragment measures 30 mm across its widest section by 21 mm thick, the other being slightly less robust. There are cell spaces in the middle indicating that they were not pachyostotic as occurs in some bottom dwelling plesiosaurians such as in the Lower Jurassic plesiosaurs from Mt Morgan in Queensland (Cruickshank, pers. observ.) first described by Bartholomai (1966), and in an undescribed new genus from the Oxford Clay (Callovian) of England (Cruickshank et al. 1996).

SUMMARY AND CONCLUSIONS

Isolated bones of plesiosaurians from the Middle Jurassic Colalura Sandstone (Bajocian) near Geraldton include the oldest possible elasmosaurid known from Australia, based on a well-preserved pectoral vertebra, as well as a caudal vertebra and an isolated phalange of more typical plesiosaurians.

The only known Mesozoic vertebrate of Berriasian age known from Australia is represented by a single cervical vertebra of cf. Leplocheidus sp. from the subsurface Barrow Group offshore near Exmouth, Western Australia.

Late Cretaceous vertebrae, teeth and rib fragments from the ?Turonian Molecap Greensland indicate the presence of large elasmosaurid plesiosaurs from Western Australia, having similar size range to that of Mansisaurus from New Zealand (up to 14 metres length).

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Reproduction and diet in four species of burrowing snakes (Simoselaps spp.) from southwestern Western Australia

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Abstract - The reproductive pattern and diet of four Simoselaps species were examined from 259 museum specimens collected from southwestern Western Australia. Few reproductively active females were recorded from the four species (S. bertholdi, S. bimaculatus, S. calonotos and S. fasciolatus) but yolked ovarian follicles and oviductal eggs were observed between October and February with a peak in November and December. Male S. bertholdi had significantly larger testes in October than other months, but no significant seasonal variation was apparent in the small adult sample of other species. The prey of all species consists of scincid and pygopodid lizards. There is a pronounced separation in the diet of S. bertholdi and S. calonotos with the former feeding on surface dwelling skinks and the latter on fossorial skinks and pygopodids.

INTRODUCTION

The knowledge of the biology of Australian snakes has expanded rapidly over the past two decades (Shine 1991). A considerable amount of new information has resulted from detailed examination of museum specimens for both their reproductive and dietary information (Shine 1983, 1984a, 1984b, 1986, 1988).

Previous studies of burrowing snakes in the genera Neelaps, Simoselaps and Vernicella document the reproductive pattern and season, size at maturity, inferred growth rates and diet (Shine 1984a). These data were acquired from 953 specimens of 13 species in collections at Australian museums and were collected over extended time frames from species, often with large geographic ranges, that covered numerous climatic zones. Shine (1984a) found that there was a marked season of reproductive activity in these species; that at least five species were oviparous with larger females having larger clutches; that females were larger than males and that there was a clear specialisation in the diet of many species.

A study of 736 specimens of 11 species of Simoselaps and Vernicella occurring in Western Australia (Clarke and How 1995) showed that it was possible to determine the sex of each individual by recording the tail to body ratio of specimens. Females of all species had smaller ratios than males and these ratios did not overlap (Clarke and How 1995).

This study examines the reproductive biology and diet of four of the six species of Simoselaps [S. bertholdi (Jan), S. bimaculatus (Duméril, Bibron and Duméril), S. calonotos (Duméril, Bibron and Duméril) and S. fasciolatus (Günther)] that are broadly sympatric in southwestern Australia. Together with S. semifasciatus ( Günther) these four species may occur syntopically in several sandplain habitats on the Swan Coastal Plain (How and Dell 1990). Southwestern Australia has a pronounced Mediterranean climate with cool wet winters and dry hot summers; a climate that invokes a period of pronounced reproductive activity in the spring and early summer in several lizard species (Chapman and Dell 1985; How and Kitchener 1983; How et al. 1986, 1987, 1990). It is also a region where the diversity of potential lizard prey items is well documented (How and Dell 1993). Of the two sympatric species not considered in this study, S. semifasciatus has a markedly specialised dietary and reproductive pattern (Shine 1984a), while S. littoralis Storr, although represented in collections, is the focus of an independent study (Jennings, personal communication).

METHODS

Specimens in the collections of the Western Australian Museum were selected to encompass the winter-rainfall dominated biogeographic regions, approximating the area of southwestern Australia west of a line from Geraldton to Esperance (Figure 1).

Specimens were measured to the nearest millimetre for both snout to vent length (SVL) and

Methods...

Figure 1  Distribution of *Simosclaps bertholdi* (□), *S. bimaculatus* (▲), *S. calonotos* (★) and *S. fasciolatus* (●) specimens from southwestern Australia examined for this study. The outline of the Interim Biogeographic Regionalisation for Australia (IBRA) regions of southwestern Australia are also depicted.

tail to vent length (TVL). After dissection of the lower abdomen with scissors the gonads were measured to the nearest 0.01 of a millimetre using digital callipers. The length (l) and width (w) of each testis was recorded as was the length and width of all yolked ovarian follicles and oviductal eggs. The volume of each testis was combined to provide a measure of testes volume, while clutch volume was calculated by combining the volumes of individual oviductal eggs.

Stomach contents were removed for later examination and identification. Prey items were identified to the species level by comparison with the extensive reference material of lizard taxa in the collections of the Western Australian Museum.

Calculations were made on the volume of testes, yolked ovarian follicles or oviductal eggs using the formulae for a prolate spheroid:

\[ \text{Vol.} = \frac{4}{3}\pi(w/2)(l/2) \]

The number of specimens of each *Simosclaps* species examined was: *S. bertholdi* 117; *S. bimaculatus* 52; *S. calonotos* 62; *S. fasciolatus* 28. These comprised 32%, 75%, 94% and 55% of individuals that had been examined previously by Shine (1984a) for the respective species.

Statistical comparisons were made using the Statistix (1996) program. Significant ANOVA's were further examined using the Least Significant Difference test (α=0.05) to compare means.

**RESULTS**

**Reproduction**

**Maturity**

The size range of adults and the number of adults of each sex of *Simosclaps* examined during this study are presented in Table 1.

The sample sizes of *Simosclaps* species available from southwestern Australia were small and, as such, probably present a very conservative estimate of size at sexual maturity amongst the species of *Simosclaps* examined in this study.
Consequently, adult specimens were determined as those larger than the smallest reproductively active specimen examined in either this study or that of Shine (1984a), who examined the reproductive state of a larger sample of each of these Simoselaps species from throughout their range. Table 1 indicates the size range of adults of both sexes determined from this study and by Shine (1984a).

The SVL of the smallest female with yolked
ovarian follicles or eggs for each *Sinioselaps* species in our samples from southwestern Australia was 172 mm in *S. berlholdi*, 237 mm in *S. bimaculatus*, 226 mm in *S. calonotos* and 288 mm in *S. fasciolatus*. These data are in close agreement with those of Shine (1984a).

Male reproductive maturity was assessed from a plot of testes volume on SVL and determined as occurring at a size above the smallest male with markedly enlarged testes size (Tables 1, 2). These sizes are again in close agreement with those of Shine (1984a), who used the opaqueness of efferent ducts as an additional criterion for determining maturity in males.

### Reproductive Season

All females contained small ovarian follicles throughout the year, but very few females from southwestern Australia had oviductal eggs or enlarged yolked ovarian follicles.

The proportion of adult females that were reproductively active in each month of collection is presented in Figure 2. Reproductive activity generally occurred between October and February with a peak in November, December and January.

Reproductively active individual female *S. berlholdi* were recorded in November (7 eggs, 1 egg + 1 yolked follicle), December (5 yolked follicles) and January (5 eggs); reproductively active *S. bimaculatus* occurred in December (3 eggs), January (2 eggs) and February (2 yolked follicles), the two reproductively active *S. fasciolatus* were in November (4 eggs) and December (5 eggs), while two reproductively active *S. calonotos* occurred in October (4 eggs) and December (3 eggs) and another female had a small, slightly yolked follicle in May.

The volume of the testes of adult *Sinioselaps* males showed no significant variation between months, except in *S. berlholdi*. In *S. berlholdi* testes volume was significantly larger in October than in November, June, September, December, January, August and April, but not other months (Table 2). In all other species the monthly sample sizes were very small and, although the largest testes volumes were recorded in spring for *S. bimaculatus*, summer for *S. calonotos* and spring-summer for *S. fasciolatus*, the monthly variation was not statistically significant (Table 2).

### Diet

The food items in the stomachs of specimens from the collections of the Western Australian Museum are presented in Table 3. The majority of specimens had empty stomachs. Most of the prey items were identifiable to the species level and consisted of scincid and pygopodid lizard species. The large number of skink tails present in the stomachs were identified to species level by comparison with the extensive reference material in the collections of the Western Australian Museum.

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### Table 1

Size range and number of each sex for the adult specimens of *Sinioselaps* species examined in this study and by Shine (1984a).

<table>
<thead>
<tr>
<th>STUDY</th>
<th><em>S. berlholdi</em></th>
<th><em>S. bimaculatus</em></th>
<th><em>S. calonotos</em></th>
<th><em>S. fasciolatus</em></th>
<th><em>S. semifasciatus</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult δ δ</td>
<td>147–196(44)</td>
<td>244–339(15)</td>
<td>171–280(25)</td>
<td>201–306(10)</td>
<td>–</td>
</tr>
<tr>
<td>Adult θ θ</td>
<td>172–264(33)</td>
<td>237–406(22)</td>
<td>226–254(25)</td>
<td>288–363(9)</td>
<td>–</td>
</tr>
<tr>
<td>Adult θ θ–Shine</td>
<td>164–312(98)</td>
<td>264–406(22)</td>
<td>186–251(32)</td>
<td>231–352(13)</td>
<td>196–334(74)</td>
</tr>
</tbody>
</table>

---

### Table 2

The testes volumes (mm³) of adult males of each *Sinioselaps* species. Data are presented by month of collection and as mean volume, standard deviation and sample size.

<table>
<thead>
<tr>
<th>MONTH</th>
<th><em>S. berlholdi</em></th>
<th><em>S. bimaculatus</em></th>
<th><em>S. calonotos</em></th>
<th><em>S. fasciolatus</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>16.2±16.2 (2)</td>
<td>14.6 (1)</td>
<td>46.0±33.2 (5)</td>
<td>103.8 (1)</td>
</tr>
<tr>
<td>February</td>
<td>19.6 (1)</td>
<td>23.5 (1)</td>
<td>–</td>
<td>104.4±99.0 (2)</td>
</tr>
<tr>
<td>March</td>
<td>43.0±48.3 (2)</td>
<td>– (1)</td>
<td>45.1±66.1 (2)</td>
<td>–</td>
</tr>
<tr>
<td>April</td>
<td>12.8±00.7 (3)</td>
<td>9.5 (1)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>May</td>
<td>43.0±56.0 (2)</td>
<td>97.2 (1)</td>
<td>25.4 (1)</td>
<td>–</td>
</tr>
<tr>
<td>June</td>
<td>23.7±11.5 (3)</td>
<td>– (1)</td>
<td>21.5±14.4 (5)</td>
<td>–</td>
</tr>
<tr>
<td>July</td>
<td>40.6±08.8 (2)</td>
<td>30.2 (1)</td>
<td>9.1 (1)</td>
<td>–</td>
</tr>
<tr>
<td>August</td>
<td>15.2±01.8 (2)</td>
<td>25.2 (1)</td>
<td>18.6±02.0 (3)</td>
<td>72.6 (1)</td>
</tr>
<tr>
<td>September</td>
<td>20.8±14.3 (4)</td>
<td>50.8±15.0 (2)</td>
<td>18.0±03.1 (3)</td>
<td>133.2 (1)</td>
</tr>
<tr>
<td>October</td>
<td>64.5±30.2 (6)</td>
<td>80.2±79.5 (4)</td>
<td>39.2 (1)</td>
<td>85.7±33.4 (2)</td>
</tr>
<tr>
<td>November</td>
<td>27.3±10.9 (7)</td>
<td>– (1)</td>
<td>19.0±03.7 (3)</td>
<td>103.5 (1)</td>
</tr>
<tr>
<td>December</td>
<td>20.5±14.4 (7)</td>
<td>23.3±08.4 (3)</td>
<td>38.2 (1)</td>
<td>100.0 (1)</td>
</tr>
</tbody>
</table>
The majority of stomachs with food contained only a single item. However, three S. bertholdi specimens contained either two or three bodies of Menetia-greyii Gray in their stomachs, while one S. calonotos had two Lerista praepedita (Boulenger) bodies and another two L. praepedita tails. The Ctenotus fallens Storr in the stomach of S. fasciolatus Ctenotus fallens mm with whole prey.

Enlarged yolky follicles were also recorded for S. bertholdi in December and in S. bimaculatus collected as late as February. One anomalous case of a small but yolked ovarian follicle was observed in a S. calonotos collected in May, the same month as one S. bertholdi was observed with enlarged follicles by Shine (1984a).

The small sample sizes of most taxa over the reproductive season precludes a definitive assessment of the proportion of adult females reproductively active during this period. The fact that all species except S. calonotos have one month during the reproductive season when most females are reproductively active suggests that adult females could breed each year. The extended period over which Sinioselaps females can be gravid supports this, as well as indicating that there could be considerable annual variation in the proximate factors determining the onset of reproduction. The evidence from this study would tend to support Shine’s (1984a) suggestion that only a single clutch of eggs is produced annually.

DISCUSSION

Shine (1984a) determined from his detailed examination of museum specimens that all species of Neelaps and Sinioselaps were oviparous. Vitellogenesis commenced in Sinioselaps species during the late spring (October-November) followed by ovulation and oviposition during the summer months of December-January (Shine 1984a). This pattern of spring and early summer reproductive activity is reflected in most of the species examined in this study from the southwest of Western Australia. However, the period of reproductive activity in the genus may be longer than previously determined. Oviductal eggs were found in S. calonotos collected during October and in S. fasciolatus and S. bertholdi in November.

Table 3

<table>
<thead>
<tr>
<th>PREY SPECIES</th>
<th>S. bertholdi</th>
<th>S. bimaculatus</th>
<th>S. calonotos</th>
<th>S. fasciolatus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aprasia repens</td>
<td>1</td>
<td>-</td>
<td>4(1)</td>
<td>-</td>
</tr>
<tr>
<td>Ctenotus fallens</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Eremaescincus richardsonii</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hemiurus quadrilineatus</td>
<td>1(1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lerista elegans</td>
<td>6(4)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lerista lineata</td>
<td>-</td>
<td>1(1)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lerista praepedita</td>
<td>1(1)</td>
<td>-</td>
<td>7(2)</td>
<td>1(1)</td>
</tr>
<tr>
<td>Lerista lineopunctulata</td>
<td>1(1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Menetia-greyii</td>
<td>7</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Plant material</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Reptile egg</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Stomachs with prey (tails)</td>
<td>19(7)</td>
<td>1(1)</td>
<td>12(3)</td>
<td>3(1)</td>
</tr>
<tr>
<td>Unidentifiable fragments</td>
<td>5</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Total stomach examined</td>
<td>117</td>
<td>52</td>
<td>62</td>
<td>28</td>
</tr>
</tbody>
</table>

The number of individual Sinioselaps specimens from southwestern Western Australia with prey items in their stomachs. The number with only tails of prey species is indicated in brackets.
The pronounced bias towards males in the sex ratios of Simoselaps captured in natural populations and noted in Table 1 is the subject of a separate study (How, unpublished data).

Many snakes have been found to be specialist predators on lizards (Shine 1991). Some only specialise on skinks, such as the small-eyed snakes [Cryptophis nigricinctus ( Günther) and C. pallidiceps (Günther)] of eastern Australia which forage nocturnally for sleeping skinks (Shine 1984b), and the eight species of Urochis (Shine 1988), which have between 83% and 100% of their diet composed of scincid lizards. In the study of diets of eleven species of the small nocturnal Neelaps and Simoselaps, Shine (1984a) showed that most were predators on skinks, two also preyed on pygopodids and three specialised on the eggs of squamate reptiles.

A major finding of our study is the clear separation in the prey species of S. bertholdi and S. calowatos in southwestern Australia. The former feeds principally on epigaeic lizard species and the latter on fossorial lizard species (Table 3). This separation was not apparent in the earlier study by Shine (1984a) where a broad array of scincid and pygopodid lizard species was consumed by each species. The dietary information on S. biuvaculatus and S. fasciatus is inadequate to determine if they have a specialised dietary niche in southwestern Australia where up to six species of Simoselaps are broadly sympatric. However, the relative abundance of prey species has been assessed in five habitats at Bold Park near Perth, where five species of Simoselaps are sympatric (How, unpublished data).

One of the six sympatric Simoselaps species in southwestern Australia (S. semifasciatus) is known to be a specialist feeder on squamate eggs (Shine 1984a). The specialisation of S. semifasciatus to feeding on squamate eggs was a principal reason that this species was not examined along with other Simoselaps during this study. This species was also shown by Shine (1984a) to have the most restricted reproductive activity seasons of all the Neelaps and Simoselaps examined by him with yolked ovarian follicles restricted to the months of November and January; no oviductal eggs were recorded. This period of reproductive activity in S. semifasciatus coincides with the peak period of oviposition of eggs by squamate reptiles in southwestern Australia, viz. late-spring to early summer (Chapman and Dell 1985, How et al. 1986, 1990), while November-December is also the peak period of activity in naturally occurring populations of the species near Perth. This restricted period of peak activity by adults raises the question of the trophic pattern of hatchling S. semifasciatus, which should emerge after the hatching of eggs of their principal prey species in February and March.

The stomach contents of several Simoselaps individuals contained only tails of skinks which were not associated with any other part of the body. This demonstrates that tails are often the only body-part of the prey consumed. Tail harvesting by predators has been recorded previously by desert pygmy varanids (Varanus gilleni Lucas and Frost, V. caudolineatns Boulenger) on the tails of geckos (Pianka 1969), while Simoselaps littoralis on the west coast of Western Australia feeds extensively on the tails of lizards (Jennings, personal communication).

Five species of Simoselaps in southwestern Australia show a strong seasonality in reproductive pattern with ovulation occurring in the late spring and early summer period, a pattern similar to many other southwestern reptile taxa. It is also apparent that there is a strong dietary niche separation in at least three of the five species which may, in part, explain their sympathy in southwestern Australia.

ACKNOWLEDGEMENTS

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Biology of burrowing snakes

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Abstract – The sponge genus *Caulospongia* is reviewed and redefined to accommodate eight closely related species that belong to the genus. Four new species, *Caidospongia amplexa*, *C. reticulata*, *C. venosa* and *C. biflabellata* are described, and *C. penantula* (Lamarck, 1814), *C. perfoliata* (Lamarck, 1814), and *C. plicata* Saville Kent (1871) are redescribed with reference to the type specimens and new material. *C. elegans* (Lendenfeld, 1888) is redescribed from the type material. The scope of the genus is discussed with respect to morphological and skeletal characters and its location within the family Suberitidae is confirmed in the light of these characters. As a consequence of examination of type material the synonymy of the genus *Plectodendron* Lendenfeld (1888) with *Caidospongia* Saville Kent (1871) is confirmed. A preliminary assessment is made of the biogeography of the genus, which is predominantly Western Australian.

INTRODUCTION

In 1814, Lamarck described *Spongia perfoliata* and *S. pennatula*, two species of stalked sponges with an unusual foliaceous morphology. Their common feature was to have a sponge body composed of leaf-like lobes around a central stem. Subsequently, Saville Kent (1871) established a new genus *Caidospongia* for two species he described: *C. verticillata* and *C. plicata*. He established the genus for sponges with a central stem surrounded by leaf-like whorls or spiral convolutions and with a skeleton of fibre and spicules. Saville Kent did not mention the material described by Lamarck (1814) and it is assumed that he was unaware that species had previously been described that were congeneric with *C. verticillata* and *C. plicata*. Bowerbank (1876) also failed to refer to previous publications that described species with this unusual morphology when he described a specimen collected from Fremantle, Western Australia as *Chalina verticillata*. Topsent (1932) noted this incredible lack of knowledge of earlier published references by both Saville Kent and Bowerbank when he redescribed Lamarck's species.

Meanwhile, in 1888, Lendenfeld had defined another new genus *Plectodendron* with the type species *P. elegans* collected on the New South Wales coast. This genus was closely related to *Caulospongia* as it had tylosyles for spicules and fibre in the skeleton, but in this genus the sponge body extended from a central stalk into a regular branching network, and bore no resemblance to the three dimensional whorls characteristic of *Caulospongia*. When Hallmann (1914) redescribed *P. elegans* he synonymised *Plectodendron* with *Caulospongia* on the basis of identical skeletal and spicule morphology. Since this time no further work has been carried out on these unusual sponges. Hooper (1984) mentioned a specimen of *C. perfoliata* collected from the Timor Sea, and Hooper and Wiedenmayer (1994) retain the synonymy of *Plectodendron* with *Caulospongia* and list three valid species,

1. *C. elegans* (Lendenfeld, 1888)
2. *C. pennatula* (Lamarck, 1814)
3. *C. perfoliata* (Lamarck, 1814) with the synonyms:
   - *C. plicata* Saville Kent, 1871
   - *C. verticillata* Saville Kent, 1871
   - *Chalina verticillata* Bowerbank, 1876

Some questions became obvious as a consequence of the review of the literature on these sponges summarised above.

- Should the genus *Plectodendron* remain synonymised with *Caulospongia*?
- How many valid species of *Caulospongia* are there?
- Is the family Suberitidae, order Hadromerida, the most appropriate taxon for the genus?

Examination of the collections at the Western Australian Museum found 12 wet specimens and numerous dry specimens of *Caulospongia*; the latter are beachwash material and in a condition too poor for descriptive purposes. Beachwash specimens of
Caulospongia are regularly found on local Perth beaches after winter storms. Five additional wet specimens have since been added to the collection, with good in situ colour photographs and habitat descriptions. Four of these specimens were collected from the South West coast (K. Bancroft and CALM; J. Fromont) and the other from the Abrolhos Islands (J. Fromont). The abundance of preserved material indicated the prevalence of the genus in WA waters, and prompted a redescription and re-evaluation of species. This examination immediately indicated a suite of problems, the first being to determine how many species were represented in the WAM collections, with the second and related problem being the ability to discriminate precisely between these morphologically similar species. Finally, defining the boundaries of the genus Caulospongia also appeared to be very complex. As an aid to resolving these problems additional material was loaned from the Northern Territory Museum of Arts and Sciences, the South Australian Museum, and the Queensland Museum. The total number of wet specimens available for examination was 37, and all available type material was also examined (Table 1).

MATERIALS AND METHODS

Material from various museums (listed at the end of this section) was examined during the course of this study. Wet specimens were preserved in 70% ethanol. Skeletal structure and spicule morphology were examined using light microscopy. Spicules were prepared by boiling small pieces of sponge, including ectosome and choanosome, in concentrated nitric acid, followed by two consecutive washes of distilled water and two of absolute alcohol. Spicule extracts were dried on a glass slide and mounted in DePeX, Gurr Products. Spicule measurements are based on 15 spicules per specimen selected at random. The skeleton was prepared by cutting a representative section at right angles to the surface of the sponge, dehydrating it through an ascending ethanol series, clearing in xylene and infiltrating in paraffin wax (Histoplast, Shandon Elliot) using an automatic tissue processor on a nine hour cycle. The sponge tissue was further infiltrated with paraffin under a vacuum of 635mm Hg for 30 minutes prior to embedding. Blocks were sectioned at 90 μm thickness with a Leitz slide microtome, and section rolling was eliminated by placing filter paper, moistened with distilled water, on top of the paraffin block. Sections were placed on a glass slide smeared with egg albumin for adhesion, dried overnight at 60°C and dehydrated in two changes of xylene. They were mounted with Eukitt, Agar Scientific.

Abbreviations used in the text: AIMS/NCI, Marine Bioproducts Group, Australian Institute of Marine Science, (Zoological collections now housed in the QM, Brisbane); AM, Australian Museum, Sydney; BMNH Natural History Museum, London; CALM, Department of Conservation and Land Management, Perth; MNHN, Museum National d'Histoire Naturelle, Paris; NTM, Northern Territory Museum of Arts and Sciences, Darwin; QM, Queensland Museum, Brisbane; SAM, South Australian Museum, Adelaide; WAM, Western Australian Museum, Perth.

Table 1 Type material relevant to this study.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>AUTHOR/YEAR</th>
<th>LOCALITY</th>
<th>MATERIAL EXAMINED</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spongia perfoliata</td>
<td>Lamarck, 1814</td>
<td>Seas of Australia (Peron &amp; Leseur)</td>
<td>Holotype: MNHN LMIM DT 3368, dry</td>
<td></td>
</tr>
<tr>
<td>Spongia pennatula</td>
<td>Lamarck, 1814</td>
<td>Shark Bay, WA (Peron &amp; Leseur)</td>
<td>Holotype: MNHN LBIM DT 583, dry</td>
<td></td>
</tr>
<tr>
<td>Caulospongia verticillata</td>
<td>Saville Kent, 1871</td>
<td>North Australia</td>
<td>Not examined, Type destroyed</td>
<td></td>
</tr>
<tr>
<td>Caulospongia plicata</td>
<td>Saville Kent, 1871</td>
<td>No locality data</td>
<td>Holotype: BMNH 1870:12:22:2, dry</td>
<td>Beachwash specimen</td>
</tr>
<tr>
<td>Caliina verticillata</td>
<td>Bowerbank, 1876</td>
<td>Fremantle, WA</td>
<td>Holotype: BMNH 1877:5:21:6, dry</td>
<td>Beachwash specimen</td>
</tr>
<tr>
<td>Plectodendrion elegans</td>
<td>Lendenfeld, 1888</td>
<td>Broughton Island, NSW</td>
<td>Lectotype: AM G9186, wet</td>
<td></td>
</tr>
<tr>
<td>Plectodendrion elegans</td>
<td>Lendenfeld, 1888</td>
<td>Port Jackson, NSW</td>
<td>Paralectotype: AM Z5221, wet</td>
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<tr>
<td>Plectodendrion elegans</td>
<td>Lendenfeld, 1888</td>
<td>Port Jackson, NSW</td>
<td>Paralectotype: AM Z5271, dry</td>
<td></td>
</tr>
</tbody>
</table>
Australian species of Caulospongia

SYSTEMATICS

Order Hadromerida

Diagnosis

Megasclere skeletons composed of monactinal spicules which are usually tylostyles, subtylostyles, or styles. A size and locational distinction is usually found in the megascleres with peripheral megascleres smaller than choanosomal ones. A radial construction occurs in the outer layers but may not occur internally. Microscleres, if present, are easter or derivatives thereof (abbreviated from Hartman (1982)).

Remarks

The Hadromerida is a relatively well defined order although in some families the simplicity of skeletal characters makes lower taxonomic level determinations difficult due to the paucity of characters with which to work. The Suberitidae is the least complex family of the order in terms of skeletal architecture.

Family Suberitidae Schmidt, 1870

Diagnosis

The radial arrangement of the skeleton is evident only at the surface. The spicules have confused orientation in the deeper regions of the sponge, but in a few cases may assume a loose axial orientation. Species of this family do not commonly have a differentiation of megascleres into size categories or a restriction of megascleres to particular localities in the sponge.

Remarks

Lendenfeld (1888) located Plectodendron in the Suberitidae and Hallmann (1914) did the same with the genus Caulospongia. The definition of this family has recently been examined by Voultsiadou-Koukoura and van Soest (1993) where they noted that the majority of previous authors who had defined the family on morphological characters agreed that the confused orientation of the choanosomal skeleton was characteristic. However, they noted that the skeletons of Rhizaxine spp. and of Suberites massa are well organised with an axial component. An organised choanosomal skeletal arrangement also occurs in the genus Caulospongia. There are additional skeletal characters that Caulospongia has in common with other genera of the Suberitidae. For instance, surface brushes of spicules found in Suberites and Laxosuberites, and two characters found in most genera of this family: a single megasclere size category, and a lack of surface papillae. Caulospongia is one of the few genera in the Suberitidae that has erect growth forms, the others being some species of Suberites such as S. massa which is branching and erect and the genus Rhizaxinella which has a globular, ovoid, cylindrical, or branching morphology with a basal stalk. Most of the genera of this family are small mounds or balls (e.g. Aaptos) massive forms (e.g. some species of Laxosuberites and Suberites) or thin encrustations (e.g. Terpios, Prosuberites, and some species of Laxosuberites). Rützler and Smith (1993) noted that the family Suberitidae contained genera distinguished by shape of the adult sponge, by skeleton structure, and by spicule orientation, type and distribution.

In summary, the genus Caulospongia is most appropriately located within the family Suberitidae. The genus has simple spiculation, one size category of tylostyles, and surface brushes of spicules. The genus is unusual within this family in having a well organised choanosomal skeleton of fibre and spicules with a central axial component.

Caulospongia Saville Kent

Caulospongia Saville Kent, 1871: 616.

Plectodendron Lendenfeld, 1888: 66.

Type species

of Caulospongia: Caulospongia verticillata Saville Kent, 1871 (junior synonym of Caulospongia perfoliata (Lamarck, 1814)) by subsequent designation of Hallmann (1914).

of Plectodendron: Plectodendron elegans Lendenfeld, 1888 by monotypy.

Diagnosis

Sponges of erect morphology with a solid basal stem and either a lobed or interlocking, reticulate branching morphology, or erect fans. Spicules are a single category of tylostyles; there are no microscleres. The choanosomal skeleton is a plumed-reticulate or reticulate network of fibre cored with spicules; interstitial spicules are present. The ectosomal skeleton consists of spicule fans or brushes with a narrow or diffuse layer of spicules parallel to the surface and overlying the brushes.

Remarks

Burton (1930) designated Caulospongia plicata as "genolectotype" but this is an invalid designation, which was predated by Hallmann (1914) who designated C. perfoliata as the type of the genus. C. elegans, the sole species described in the genus Plectodendron, has identical skeletal characters to species assigned to the genus Caulospongia. It differs from species of Caulospongia only in its external morphology. In this study the redefinition of the genus Caulospongia accommodates sponges
with a reticulate branching structure previously assigned to the genus _Plectodendron_.

_Caulospongia perfoliata_ (Lamarck)  
Figures 1a–d; 2a–d; 3

_Spongia perfoliata_ Lamarck, 1814: 439.


_Caulospongia verticillata_ Saville Kent, 1871: 616, pi. 48, figure 1.

_Chalina verticillata_ (Saville Kent): Bowerbank, 1876: 769, pi. 79.

**Material Examined**

**Holotype**  
MNHN LBIM DT 3368, “Australian seas” (precise locality unknown).

**Other material**

**Australia: Western Australia:** BM 1877:5:21:6, specimen of _Chalina verticillata_ (Bowerbank, 1876), Fremantle, 32°04’S, 115°45’E; WAM Z57 West of City Beach, Station 12, 31°56’S, 115°38’E, 29 m depth, 12 October 1976, coll. L. Marsh _et al_. on RV Flinders; WAM Z58 Point Hood Reef, 33°57’S, 120°06’E, 26.8 m depth, 18 March 1997, coll. K. Bancroft, SCUBA; WAM Z59 Stream Bay, 34°29’S, 119°17’E, 11.5 m depth, 13 March 1997, coll. K. Bancroft, SCUBA; QM G310964 N. side 0.5 nm NW Charlotte Pt., Rottnest Is. 31°59’S, 115°29’E, 16 m depth, 14 March 1989, coll. AIMS/NCI, SCUBA.

**Diagnosis**

This species is characterised by having large and irregular lobes that are thick and firm. The surface has an adherent dermal membrane. The lobes of _C. perfoliata_ circumvolve a central axial hollow stem and they do not encircle the axis in one complete whorl as found in _C. amplexa_. A consistent character for this species is that the lobes turn upwards at their outer edges. This species is most like _C. amplexa_ and _C. reticulata_. However, the former species has more regular, smaller and softer lobes, and the latter species is characterised by having branches that form reticulate cross branches, not seen in either _C. perfoliata_ or _C. amplexa_.

**Description**

**Shape:** Sponges with firm, basal stems and wide, spreading, irregularly shaped lobes (Figure 1a–d). Stem within lobes is hollow. Lobes slope upwards towards the apex of the sponge.

**Dimensions:** 30–56 cm in height, stem below lobes 5.5–13 cm in length, sponge body with lobes 20–25 cm × 6–9 cm across at the widest point in the middle of the sponge body axis. Lobes are 0.3–0.5 cm thick.

**Colour:** Cream, yellow or pale yellow orange, QM G310964 pale salmon pink alive darkening to orange on collection; fawn in alcohol.

**Oscules:** Oscular canals visible over basal stem. Both surfaces of the lobes are porous, with more pores on the lower surface.

**Texture and surface characteristics:** Specimens are very firm but compressible. The surface has a dermal membrane.

**Ectosome and subectosome:** Fans consisting of a few spicules occur at the surface with a thick parallel layer of spicules beneath. This surface skeleton is 90–150 μm thick.

**Choanosome:** Beneath the ectosomal layer, tracts of spicules support the fans and in the centre of the sponge the skeleton becomes plumoreticulate (Figure 2a–d). Thick primaries, 60 μm across, are packed with ~5 spicules and surrounded by a fibre sheath. Some dark pigment occurs over the primary fibre. The secondary fibres are 30 μm wide and cored by 2–4 spicules. The basal stem has a dense fibre skeleton with dark pigmentation over yellow fibre. Fibres are up to 320 μm wide and are sparsely cored by spicules. Some of the fibres are fasciculate. Secondary fibres in the basal stem are thinner, 40–60 μm wide. A dense layer of spicules occurs parallel to the surface of the stem with few spicule fans.

**Megascleres:** (Figure 3). Tylostyles with flat nail heads frequently double or multi-bulbed. See Table 2 for dimensions.

**Remarks**

Material of this species that had been described by previous authors was examined, and conformed to the redescription presented above. Only a fragment of the type material (MNHN LBIM DT3368) was available and included the basal stalk and first basal lobe (Figure 1a). This specimen has an euctosomal skeleton of spicules at right angles to the surface with a layer of tangential spicules beneath, and towards the centre of the sponge fibre.

Table 2 Spicule measurements (μm) of specimens of _Caulospongia perfoliata_ are given as minimum-mean-maximum (n=15).

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<th>Material</th>
<th>Tylostyles</th>
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<tr>
<td>BM 1877:5:21:6</td>
<td>130-179-208 x 4-4.9-5.0</td>
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<tr>
<td>WAM Z57</td>
<td>135-179-205 x 5-5.8-8.5</td>
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<td>WAM Z58</td>
<td>145-179-203 x 5-6.5-10</td>
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<tr>
<td>WAM Z59</td>
<td>140-175-210 x 4-6.5-9</td>
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<tr>
<td>QM G310964</td>
<td>175-197-215 x 6.5-7.9-10</td>
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</tbody>
</table>
Australian species of *Caulospongia*

Figure 1 Photographs of whole specimens: a, *Caulospongia perfoliata* (Lamarck, 1814), MNHN LBIM DT 3368, fragment of basal lobe with stalk; b, *Caulospongia perfoliata* (Lamarck, 1814), specimen of *Chalinia verticillata* of Bowerbank, 1876 BM 1877:5:216, part of lobes and stalk; c, *Caulospongia perfoliata* (Lamarck, 1814) WAM Z57, with upward directed lobes; d, *Caulospongia perfoliata* (Lamarck, 1814) WAM Z58, with upward directed lobes; e, *Caulospongia amplexa* sp. nov., holotype WAM Z55, showing downturned lobes; f, *Caulospongia amplexa* sp. nov. Paratype WAM Z56, with downturned lobes.
development is apparent with fibres that are 80 μm thick and cored by 5-10 spicules. The skeleton is plumoreticulate and sometimes fasciculate centrally. The tylostyles have flattened, or occasionally, "knobbly" heads, frequently curved along the shaft and thickest in mid-axis. The drawing of the complete specimen in Topsent (1932: plate 3, Figure 4) is of an erect sponge with...
irregular lobes that slope upwards at their outer edges. This morphology is characteristic of *Caidospongia perfoliata*.

Bowerbank’s specimen (BM 1877:5:21:6) was re-examined and is dry, soft and fragile. It is a beachwash specimen with sandgrains visible throughout the lobes of the sponge. The specimen is not complete but consists principally of the basal stalk and some of the basal sponge lobes (Figure 1b). It is 19 cm long with a 12 cm long basal stalk. The lobes surround the stem in a circular fashion but are wide and frequently irregular in shape. The internal skeleton is plumose to plumo-reticulate with fibres 55 μm wide, centrally cored by 4–10 spicules. Other spicules occur without order throughout the mesohyl. The surface of the sponge has been worn away and the structure of the ectsosomal skeleton could not be determined. The tylostyles have flattened heads, some have stylote modifications or knobbly ends. The spicules are slightly curved below the head. The drawing in the publication by Bowerbank (1876: plate 79, figure 1) is of the complete specimen and depicts the lobes curving upwards at the edges, a principal distinguishing characteristic of *C. perfoliata*.

The type material of *Caidospongia verticillata* Saville Kent, 1871 is lost but from the drawing in Saville Kent (1871: plate 48, Figure 1) it too has lobes turning upwards at their outer edges. The exact locality where this specimen was collected is not known. Saville Kent (1871) noted the locality as North Australia.

**Habitat Description**

WAM Z58 was found on granite boulders with *Ecklonia*; WAM Z59 was shaded on sloping rock beneath granite boulders; WAM Z57 was with *Posidonia* and dead shells; and QM G310964 was on rocky ledges covered with algae.

**Associated Fauna**

WAM Z58 contained ophiuroids, a crinoid, isopod and a shrimp; WAM Z57 contained ophiuroids and shrimps.

*Caulospongia amplexa* sp. nov.

Figure 1e–f; 2e–f; 4

**Material Examined**

*Holotype*

WAM Z55: NW of Rosemary Island, Dampier
Archipelago, Station SO1/79/33, Western Australia, Australia, 19°57'S, 116°17'E to 19°67'S, 116°16'E, 70-71 m depth, 4 October 1979, coll. S. Slack Smith and L. Marsh on RV Soela, otter trawl.

Paratypes

Other Material

Diagnosis
Sponges of *Caulospongia amplexa* have regularly and evenly shaped lobes that circumvolve the central stem as one entire whorl. The edges of the lobes are regular and rounded. A dermal membrane is always associated with the surface, and can be peeled away in small sections. The lobes of this species consistently slope downwards at their outer edge. This species is most similar to *C. perfoliata* which has fairly wide, thick lobes circumvolving a central hollow stalk, and an adherent dermal membrane. The lobes of *C. amplexa* are relatively thick, up to 0.3 cm, but not as thick as those of *C. perfoliata* which can be 0.5 cm thick. *C. perfoliata* has irregular shaped lobes that slope upwards at their outer edge which is in marked contrast to the lobes of *C. amplexa* which slope downwards.

Description
Shape: The sponges consist of a series of downturned lobes that circumvolve the central stem of the sponge. The lobes are widest in the central region of the sponge and narrow toward the base and apex of the sponge (Figure 1c, f). The central stalk is hollow internally except for the solid basal stem below the lobed region of the sponge.

Dimensions: 20-42 cm tall, stem below lobes 8-11 cm long, sponge body with lobes 13-31 cm x 4-5 cm wide at the widest point in the centre of the sponge body axis. The lobes are 0.2-0.3 cm thick.

Colour: WAM Z53 and QM G311623 salmon to orange pink, QM G306005 and NTM Z1791 yellow, NTM Z1769, Z1803 and Z1882 yellowish brown alive; in alcohol WAM Z53 fawn to dull orange, other specimens fawn or light brown to dark brown in alcohol.

Oscules: The undersurfaces of the lobes are always finely porous; the upper surfaces are porous but the pores are less visible because of the presence of a dermal membrane.

Texture and surface characteristics: Soft compressible sponges, with firm, incompressible basal stems. The surface is smooth, finely hispid, with a dermal membrane that peels away from the underlying tissue.

on the upper surfaces of the lobes. Spicule fans, with the spicules loosely packed, occur at right angles to the surface. The pointed ends of the spicules extend slightly above the surface. A layer of spicules, parallel to the surface and also loosely packed, underlie the spicule brushes. This combined ectosomal skeleton is 250 μm wide. In WAM Z53 the ectosome is heavily pigmented with numerous orange cells so the structure of the skeleton is difficult to determine. NTM Z1791, Z2446, Z1769, Z1882 and Z1490 have foreign material at the surface and in superficial canals.

Choanosome: Beneath the fans are primary tracts of spicules, 40-45 μm wide, with the spicules loosely packed (Figure 2e, f). Between the tracts are sub-dermal spaces which are approximately 85 μm wide. Towards the centre of the lobes is a plumoreticulate skeleton consisting of fibre centrally and sparsely cored by spicules. Fibre development is most pronounced towards the centre of the sponge lobe. The stem of the sponge has a reticulate fibre skeleton with thick primary fibres, 100-200 μm thick, with 5-10 spicules loosely packed within, and with some central fasciculation. The secondary fibres are 30 μm wide and cored by approximately 5 spicules. There is dense mesohyl with interstitial spicules.

Megascleres: (Figure 4). Tylostyles with flat nail-like heads generally straight or very slightly curved apically, tapering towards the head, thickest centrally, and with a large range of lengths. Thin forms occur. There is no differentiation of spicule sizes into particular regions of the skeleton. QM G311623 has longer spicules than the other specimens examined. See Table 3 for dimensions.

Remarks
WAM Z55 (collected 4 December 1979), NTM Z1803 and NTM Z1791 (both collected 29 August 1983) and WAM Z53 (collected 20 March 1997) are reproductive. The first three specimens contain oocytes that are ~90 μm in diameter. The latter specimen contains larvae that are 500-700 μm wide.

Habitat Description
WAM Z53 and WAM Z54 occur in full light on reef outcrops surrounded by algae, hard corals and some ascidians. WAM Z56 was found on limestone reef, and QM G311623 was collected on a steep slope to 40m with coral rubble.

Associated Fauna
Numerous spionid worms cover the surface of WAM Z53; ophiuroids were found on WAM Z55, WAM Z56 and QM G306005. WAM Z56 contained a shrimp within the hollow part of the central stem and WAM Z55 had specimens of Calliostoma sp. associated with it.

Etymology
This species is named for the encircling habit of the sponge lobes around the central stem of the sponge. From the Latin amplexus: surrounding, encircling.

Caulospongia pennatula (Lamarck)
Figure 5a, b; 6a, b; 7
Spongia pennatula Lamarck, 1814: 440.

Material Examined
Holotype
MNHN LBIM DT 583, Locality: Shark Bay (estimated lat. and long.: 25°13'S, 113°43'E), Western Australia, Australia.

Other material
Australia: Western Australia: WAM Z60 Goss Passage, Beacon Island, Abrolhos, 28°29'S, 113°46'E, 31 m depth, 6 April 1978, coll. B.R. Wilson, D. Devaney (sponge 17), SCUFA. WAM Z61, Quobba, Shark Bay, 24°24'S, 113°24'E, no depth information, 7 June 1962, coll. on FRV Peron, (sponge 26). NTM Z2970 W. of Carnarvon, 24°55'S, 112°50'E, 80-85 m depth, 14 July 1987, coll. J.N.A. Hooper.

Diagnosis
This species has very wide leafy lobes with a thin adherent membrane and obvious pores visible on both surfaces. The leaves are thin; never thicker than 0.3 cm. This species is characterised by large,
Figure 5  Photographs of whole specimens: a, Caulospongia pennatula (Lamarck, 1814), holotype MNHN LBIM DI 583, showing wide lobes dried vertically; b, Caulospongia pennatula (Lamarck, 1814) WAM Z60, showing wide horizontal lobes; c, Caulospongia plicata Saville Kent (1871), holotype BM 1870:12:22:2, whole specimen showing frilly lobes; d, Caulospongia plicata Saville Kent (1871) WAM Z65, single branched form (label upside down); e, Caulospongia plicata Saville Kent (1871), NTM Z1742, multi-branched form; f, Caulospongia elegans (Lendenfeld, 1888), lectotype AM G9186, showing reticulate branches.
flat, slightly upturned leaves which are very wide unlike the lobes of the morphologically similar species Caulospongia perfoliata and C. amplexa.

Description
Shape: Sponge consists of large, flat, slightly upturned leaves which are very wide (Figures 1, 5a, b). The leaves are porous with a patterned surface produced by the outline of the underlying canals. There is a thin attached membrane superficially.
Dimensions: (specimens not complete) 17–26 cm
tall. Stem below leaves 6–15 cm long and 2 cm wide consisting of 3–4 stems coalesced. Leafy upper region of sponge 11 cm tall × 12 cm wide to 26 cm tall and 5 cm wide. Leaves are 0.1 cm thick, 0.3 cm thick in NTM Z2970.

Colour NTM Z2970 yellowish fawn; in alcohol cream or beige to c^range or medium brown.

Oscules: Oscular canals visible beneath the fine membrane and leaves porous on both sides.

Texture and surface characteristics: Thin surface membrane but missing in parts so the surface is hispid. Soft, compressible sponge.

Ectosome and subectosome: Spicule brushes occur at the surface but the spicules are not tightly packed together within them. A layer of spicules, parallel to the surface, underlie the spicule brushes, 70 μm wide. In some specimens pigment cells occur at the surface and throughout the mesohyl.

Choanosome: Beneath the brushes are primary tracts of spicules with strong fibre development, 60–100 μm wide, cored by 5–8 spicules (Figure 6a, b). Secondary fibres are 20–40 μm wide and cored by 1–4 spicules. The strongest fibre development occurs centrally, and primary and secondary fibres form a plumoreticulate skeleton curving out to the surface spicule brushes. Dark coloured grany cells, possibly pigment, overlie the central fibres. NTM Z2970 has some foreign material in the canals within the choanosome.

Megascleres: (Figure 7). Tylostyles with reduced development of the head end which is slightly rounded or flat. Spicules have long tapering points and are thickest in the middle of the shaft. See Table 4 for dimensions.

Remarks
The holotype is dried and mounted and consists of a sponge with a basal stalk 11 cm long and the lobed part of the sponge 12 cm long (Figure 5a). The lobes of this specimen are very large, up to 9 cm wide and 0.1–0.3 cm thick. In the dried state it is difficult to determine the surface features but there are numerous fine pores as noted by Lamarck (1814). The lobes are orientated vertically but this may not have been the correct orientation of them when the sponge was alive. The sponge is a medium brown colour. At the surface there is a dense skeleton with spicules at right angles to the surface as well as horizontal, forming a layer 175 μm wide. The thickest fibre tracts, 50–60 μm wide, run parallel to the surface and centrally within the sponge. The skeleton tends to be plumoreticulate. The tylostyles have flat nail heads with some stylote modifications, and are widest above the pointed end.

The other specimens examined differ from the holotype in lacking a vertical orientation to the lobes, however in life the lobes of the holotype may have had a more horizontal orientation. The intact edges of the lobes of the type are regular but both WAM Z60 and NTM Z2970 have more irregular edges to the lobes. Only the lobes of NTM Z2970 are as thick as the thickest lobes of the holotype, the other two specimens examined have lobes that are <0.2 cm in thickness. The skeleton is less ordered in the holotype than in the other specimens examined. In all other aspects the new material conforms to the holotype.

Habitat Description
WAM Z60 on bottom of channel, with sand and...
Australian species of *Caulospongia*
coral rubble and rippling from current, and NTM Z2970 on sand and shell grit.

*Caulospongia plicata* Saville Kent
Figure 5c-e; 6c-e; 8

*Caulospongia plicata* Saville Kent, 1871: 616, plate 48
Figure 2; Hallmann, 1914: 306; Burton, 1930: 673; Topsent, 1932: 88; Hooper and Wiedenmayer, 1994: 405.

Material Examined

**Holotype**

**Other material**


**Diagnosis**

This species is characterised by small, thin (<0.2 cm), and narrow lobes with undulating or "frilled" edges. This species is distinguished from other species of *Caulospongia* by the small size of the lobes and their frilled appearance. The two morphs of this species are distinguished by having single branches (shallow water forms) or multiple branches (deep water forms). Both forms have the characteristic frilled lobes that distinguish this species from all other species of *Caulospongia*.

**Description**

**Shape:** Two morphs of this species occur. Those that occur in shallow water have a single branch (WAM Z63, Z64, Z65 and QM G310450) while those that occur in deep water (NTM Z3053, Z1816, Z1742, Z1408) are multibranched (Figure 5d, e). This species has the classic *Caulospongia* shape of a central hollow stem with whorls arrayed around the outside. In this species the leaf-like extensions are more convoluted than other species of *Caulospongia*. The fronds are either perpendicular to the stem or turn upwards at their outer edge (Figure 5c-e). The fronds of this species are small and narrow, approximately 1 cm wide and <0.2 cm thick. In QM G310450, a shallow water form, the lobes are very small, often only 0.5 cm wide and some branches interconnect. The deepwater specimens are multibranched (NTM Z3053, Z1816, Z1742, Z1408) and have a single basal, solid stem with 3-5 branches extending above this in a candelabra fashion.

**Dimensions:** Single branched specimens 13-22 cm tall, 3.5-6 cm wide; multibranched specimens 33-60 cm tall, basal stem 8-11 cm long, each branch 3-5 cm wide.

**Colour:** WAM Z63 orange, QM G310450 peach-pink to orange, NTM Z3053 and Z1742 yellow, NTM Z1816 deep yellow-orange alive; in alcohol

**Figure 8** Spicules of *Caulospongia plicata*: a, holotype BM 1870:12:22:2; b, WAM Z65; c, NTM Z1742. Scale bar = 50 μm.
cream to beige, fawn or yellowish light brown or dark red brown.

Oscules: Not apparent.

Texture and surface characteristics: A very fine microhispid surface that is shiny and reflective. A thin membrane is attached to the underlying tissue, and pores are faintly apparent or not visible. The sponge has dense texture, is firm, spongy and compressible, except for the basal part of the stem which is solid and incompressible.

Ectosome and subectosome: Spicule fans occur at right angles to the surface with the pointed ends of the spicules projected outwards, forming the hispid surface. A layer of spicules 30-60 µm wide, parallel to the surface, underlie the spicule brushes.

Choanosome: Beneath the spicule fans are primary fibres with spongin development, 30-80 µm wide and centrally cored by 6-10 spicules. Secondary fibres occur that link the primary fibre in a plumoreticulate or ladder-like fashion (Figure 6c-e). The secondary fibres are 20 µm wide cored by 1-3 spicules. Towards the centre of the sponge leaves or in the central stem of the sponge the primary fibres are thick (80 µm wide), have dense spongin, and run parallel to the surface. In some specimens fasciculation of the primary fibres occurs. Interstitial spicules present, without order. No differentiation of size categories of spicules throughout the skeleton. Some specimens (WAM Z66 and NTM Z1742) incorporate some foreign material into the superficial regions.

Megascleres: (Figure 8). Tylostyles with a large range of widths and lengths, but generally short and thick. The head is flat and nail-like, or rounded. The spicules are straight or slightly curved, tapering to long points. See Table 5 for dimensions.

Remarks

The holotype was dry and consequently brittle and fragile and its colour was fawn to light brown.

It is probably a beachwash specimen judging from the amount of foreign material in the mesohyl microscopically, and macroscopically the sand distributed over the surface and throughout the body of the sponge. Part of the stem of the specimen is missing. The sponge measures 12 cm in length and is 3.5 cm at its widest point. Leaf-like structures surround the stem in whorls but are convoluted giving the sponge a “frilly” appearance (Figure 5c). The ectosomal skeleton of the holotype consists of tylostyles at right angles, as well as parallel to the surface, forming a layer 80 µm wide. In the centre of the sponge the plumose skeleton is strengthened with fibre development, 60-85 µm wide, core by up to 5 spicules. Surrounding this region the spicules occur in tracts forming a reticulate skeleton with fibre that is not as dense as it is centrally. Interstitial spicules occur without order. The spicules are tylostyles with flattened heads, slightly curved below the head (Figure 8).

Caulospongia plicata was previously synonymised with C. perfoliata by Hallmann (1914). This is clearly a good species and the name is here removed from synonymy.

Habitat Description

WAM Z63 collected with gorgonians and branching sponges; WAM Z66 collected with large sponges and soft corals, WAM Z65 on sand, NTM Z3053 and WAM Z62 on shell substrate and sand and shell grit, QM G310450 on subtidal reef flat with sediment layer, sea whips and sponges, WAM Z64 found attached to stems of seagrass in shallow water.

Associated Fauna

NTM Z3053 with ophiuroids.

Caulospongia elegans (Lendenfeld) 1888: 66.


Material Examined

Lectotype

AM G9186 (wet), Broughton Island, New South Wales, Australia, 32°37'S, 152°19'E.

Paralectotypes

Australia: New South Wales: AM Z5221 (wet) Port Jackson, 33°51'S, 151°16'E; AM Z5271 (dry), Port Jackson, 33°51'S, 151°16'E.

Diagnosis

This species is characterised by having a two

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<th>Tylostyles</th>
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<td>140-197-225 µm</td>
</tr>
<tr>
<td>NTM Z3053</td>
<td>155-184-213 µm</td>
</tr>
<tr>
<td>NTM Z1816</td>
<td>128-169-200 µm</td>
</tr>
<tr>
<td>NTM Z1742</td>
<td>130-172-200 µm</td>
</tr>
<tr>
<td>NTM Z1408</td>
<td>130-190-210 µm</td>
</tr>
<tr>
<td>QM G310450</td>
<td>155-198-215 µm</td>
</tr>
</tbody>
</table>

Table 5 Spicule measurements (µm) of specimens of Caulospongia plicata are given as minimum-mean-maximum (n=15).
Australian species of *Caulospongia*

dimensional reticulate branching morphology. The branches intermesh at right angles, giving a lattice-like appearance to the sponges. It does not have a hollow stem through the centre of the sponge as lobed species do, but does have a solid basal stalk found in all species of *Caulospongia*. This species has the same skeletal layout as other species of the genus. It is most similar morphologically to *C. reticulata* but it does not have lobes which are characteristic of the latter species.

**Description**

*Shape:* An erect branching sponge with branches interlocking at right angles, giving a reticulate, lattice morphology (Figure 5f). Basal stalk tough and solid.

*Dimensions:* Intact Pt. Jackson specimen (AM Z5221) is 17 cm tall with an incomplete basal stem. Individual branches are 0.9 x 0.6 cm. AM Z5271 is numerous dry fragments, some of which have the branching reticulate morphology characteristic of the species. The material is porous without an obvious membrane, which has probably worn off.

*Colour:* No live colour; in alcohol fawn to medium brown.

*Texture and surface characteristics:* The surface is smooth with an attached membrane, with pores faintly visible beneath.

**Ecological and substrate:** Dense spicule brushes at the surface with a layer of spicules orientated horizontally to the surface overlying the brushes.

**Choanosomal:** An irregular plumorreticulate skeleton with tracts of spicules surrounded by spongin fibre, 30–40 μm wide, and cored by 4–6 spicules (Figure 6f). The sponge skeleton is most compact centrally. Spicules also occur haphazardly in the mesohyl.

**Megascleres:** (Figure 9). Tylostyles with thickest dimension in centre of spicule, somewhat rounded tylote head. Large size range. See Table 6 for dimensions.

**Remarks**

There were three syntypes of this species in the Australian Museum. AM G9186, which has been designated lectotype in this paper, is in good condition with part of the basal stem and all of the branches intact (Figure 5f). The paralectotype from Pt. Jackson (AM Z5221) was previously registered as AM Z778, a number shared with another sponge species *Polymastia bicolor*. The register number AM Z778 has now been exclusively allocated to the specimen of *P. bicolor* and the specimen of *C. elegans* has been given the new number AM Z5221 (P. Berents, pers.comm.) This specimen is in good condition and is a large fragment with some of the basal stem and branches. Some dry material, previous registration number AM Z508, consists of numerous fragments (<1.5 cm long) that were thought to be a mixture of fragments of *Hircinia gigantea* and *C. elegans*. However, the larger fragments are of *C. elegans* and all the fragments look identical. The condition of this material is a consequence of it being attacked by rats in 1941. A large intact wet specimen of *H. gigantea* has been assigned the number AM Z508 and the fragments of *C. elegans* have been given the new registration number AM Z5271 (P. Berents, personal communication). Only these three specimens exist in the Australian Museum, not four, as suggested by Hooper and Wiedenmayer (1994), who thought the label referring to two specimens on one of the jars, was referring to two specimens of *C. elegans* (J. Hooper, personal communication). However, these sponges were one of the mixed lots described above.

![Figure 9 Spicules of *Caulospongia elegans*. Lectotype AM G9186. Scale bar = 50 μm.](image_url)

**Table 6** Spicule measurements (μm) of specimens of *Caulospongia elegans* are given as minimum-mean-maximum (n=15).

<table>
<thead>
<tr>
<th>Material</th>
<th>Tylostyles</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM G9186</td>
<td>148–183–220 x 5–7.4–10</td>
</tr>
<tr>
<td>AM Z5221</td>
<td>145–198–223 x 6.5–9–10</td>
</tr>
<tr>
<td>AM Z5271</td>
<td>140–183–200 x 7.5–9.4–12.5</td>
</tr>
</tbody>
</table>
Caulospotgia reticulata sp. nov.

Figure 10a,b; 11a,b; 12

Material Examined

Holotype
WAM Z67, Reef off mouth of Capel River, Western Australia, Australia, 33°46'S, 115°08'E, 3-6 m depth, 19 February 1984, coll. L. Marsh.

Paratypes


Diagnosis

In this species specimens may have lobes with interconnections that circumvolve a central stem, or lobes that are much reduced in dimensions and form a lattice reticulation, without a central stem, that has similarities to C. elegans. This species differs from C. elegans in retaining lobes, while specimens of C. elegans have branches that lack lobes of any form and are rounded, smooth and interconnected.

Description

Shape: WAM Z67 is an erect sponge with reticulate branches and small lobes, flattened into two dimensions (Figure 10a). SAM IS403 has a lobed reticulation like WAM Z67 but the upper 6 cm of the sponge is flattened into vertical plates. SAM IS402 is a series of interconnected short blunt nodes with a hollow central stem, but some of the leaf-like appendages form connections in a reticulate manner (Figure 10b).

Dimensions: WAM Z67: 16-29 cm long with a basal stem 10 cm long, branched region of sponge 19 cm, at widest point: 7-11 x 2 cm wide. Thickness of networked branches: 0.2-0.5 cm.

Colour: Live colour unknown, cream, beige or fawn in alcohol.

Texture and surface characteristics: Firm but compressible. Pores over surface faintly visible macroscopically beneath an adherent dermal membrane.

Lectosome and subectosome: Spicule fans or brushes and a layer of parallel spicules overlying these, 70-100 μm wide. Ectosomal skeleton of South Australian specimens more diffuse than the WAM Z67 material from Capel River.

Choanosome: Beneath the ectosomal layer is a plumoreticulate fibre skeleton with strong fibre development (Figure 11a, b). Primary fibres are 50-80 μm wide cored by 4-6 spicules, secondary fibres 20-50 μm wide cored by 1-3 spicules. Interstitial spicules present. In the basal stem of the sponge the fibre component of the skeleton extends to the ectosomal spicule brushes.

Megascleres: (Figure 12). Tylostyles usually with flat nail heads, some rounded stylote or knobbly modifications. See Table 7 for spicule dimensions.

Remarks

The three specimens described above form a transition series from the lobed forms, with central hollow stem typical of most species of Caulospotgia and found in SAM IS403, to the reticulate morphology characteristic of C. elegans and to an extent seen in WAM Z67. SAM IS402 is intermediate, having reticulate processes connecting the lobes which link it with the morphologies of the other two specimens. C. reticulata is a transitional morphology between typical Caulospotgia with lobes, and reticulate branching, two dimensional forms seen in C. elegans.

The spicules of the South Australian specimens are longer and thinner than those of the South West Australian specimen.

Habitat Description

No details available.

Etymology

This species is named for the connections that form between the lobes giving a lattice component to the external morphology. From the Latin reticulatus: made like a net.

Table 7 Spicule measurements (μm) of specimens of Caulospotgia reticulata are given as minimum-mean-maximum (n=15).

<table>
<thead>
<tr>
<th>Material</th>
<th>Tylostyles</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAM Z67</td>
<td>140-172-200 x 5-7.2-9.5</td>
</tr>
<tr>
<td>SAM IS403</td>
<td>165-194-220 x 4-4.9-6</td>
</tr>
<tr>
<td>SAM IS402 (NTM Z0003116)</td>
<td>155-194-223 x 3.5-4.5-5</td>
</tr>
</tbody>
</table>

Caulospotgia venosa sp. nov.

Figure 10c; 11c; 13

Material Examined

Holotype
SAM IS405 (NTM Z3742) 8 km NNW of Pt. Riley, Spencer Gulf, South Australia, Australia, 33°48'S, 137°34'E, 20 m depth, 13 December 1988, coll. K Gowlett Holmes and P. Briggs on FV Kara George.
Australian species of *Caulospongia*

Figure 10 Photographs of whole specimens: a, *Caulospongia reticulata* sp. nov., holotype WAM Z67, with reticulations and lobes; b, *Caulospongia reticulata* sp. nov., SAM IS402, with lobes that interconnect; c, *Caulospongia venosa* sp. nov., holotype SAM IS405, showing veins on lobes; d, *Caulospongia biflabellata* sp. nov., holotype WAM Z267, fragment of fan showing lobes; e, *Caulospongia biflabellata* sp. nov., QM G311009, whole specimen showing bilobed form of fan.
Figure 11 Photographs of skeletal organisation: a, Caulospongia reticulata sp. nov., holotype WAM Z67, showing fibre development beneath surface; b, Caulospongia reticulata sp. nov., SAM IS402, surface and underlying fibre development; c, Caulospongia venosa sp. nov., holotype SAM IS405, showing surface and internal skeleton; d, Caulospongia biflabilata sp. nov., holotype WAM Z267, showing thick surface skeleton and internal reticulation; e, Caulospongia biflabilata sp. nov., QM G311009, showing thick surface skeleton and internal reticulation. Scale bar = 200 μm.

Diagnosis
This species is distinctive from all other species of Caulospongia in having plumose lines on the surface of the lobes, very porous lobes with an open texture, and a knobby upper surface. The layout of the skeleton is similar to other species of Caulospongia although it is not as dense and compact as some species like C. biflabilata. No other species of Caulospongia have the veined lobes characteristic of this species.

Description
Shape: This is an erect sponge with the classic Caulospongia shape of whorls of sponge around a central axial hollow stem. However, the thick, large lobes have major superficial differences from other
Australian species of *Caulospongia*

Figure 12 Spicules of *Caulospongia reticulata* sp. nov.: a, holotype WAM Z67; b, SAM IS402. Scale bar = 50 \(\mu\)m.

Table 8 Spicule measurements (\(\mu\)m) of specimens of *Caulospongia venosa* are given as minimum-mean-maximum (n=15).

<table>
<thead>
<tr>
<th>Material</th>
<th>Tylostyles</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAM IS405 (NTM Z3742)</td>
<td>143-180-223 x 4-4.6-5</td>
</tr>
</tbody>
</table>

species of *Caulospongia*. Extending from the central stem to the outer edge of the lobes are plumose lines that look like the leaf veins of plants (Figure 10c). The upper surface of the sponge is irregular and convoluted with small nodes or veins. The underside of the lobes have large pores.

**Dimensions:** Specimen incomplete; overall size 27cm; stalk 12 cm incomplete lobed part of sponge 15 cm, lobes 5 cm wide, 0.4 cm thick.

**Colour:** Live colour unknown, beige with pinkish tinge in alcohol.

**Texture and surface characteristics:** Soft, compressible, spongy. Surface porous, in some areas with an attached dermal membrane, otherwise hispid.

**Ectosome and subectosome:** Spicule fans or brushes at the surface form a loose palisade up to 200 \(\mu\)m wide. The layer of parallel spicules overlying these is thin and the spicules are sparse. There is some thickening of the mesohyl at the outer surface edge and around the canals.

**Choanosome:** Beneath the ectosomal layer is a reticulate fibre skeleton cored with spicules (Figure 11c). Primary fibres are 40 \(\mu\)m wide cored by -7 spicules, secondary fibres 10–20 \(\mu\)m wide cored by 1–3 spicules. The fibres are thicker toward the centre of the lobes and the skeleton more plumoreticulate with the thickest fibres running parallel to the surface. Primary fibres are 70 \(\mu\)m wide cored by up to 10 spicules, secondary fibres are 40–70 \(\mu\)m wide and cored by 1–3 spicules. Interstitial spicules present.

**Megascleres:** (Figure 13). Tylostyles thin, gently curved along their length, with flattened nail-like heads or with small knobbed or stylote modifications. See Table 8 for spicule dimensions.

**Remarks**

This specimen was reproductive with oocytes 40 \(\mu\)m wide visible in the mesohyl (date of collection: 13 December 1988).

**Habitat Description**

Trawl grounds.

Figure 13 Spicules of *Caulospongia venosa* sp. nov., holotype SAM IS405. Scale bar = 50 \(\mu\)m.
Etymology
This species is named for the veins, plumose lines of thickened tissue, that occur on the lobes. From the Latin venosus: veined.

*Caulospongia biflabellata* sp. nov.

**Material Examined**

**Holotype**
WAM Z267 Limestone reef flat, Cheyne Beach, Western Australia, Australia, 34°48'S, 118°00'E, 10 m depth, 2 November 1997, coll. J. Fromont, SCUBA.

**Paratype**
Australia: Western Australia: WAM Z268 Limestone reef flat, Cheyne Beach, 34°48'S, 118°00'E, 10 m depth, 2 November 1997, coll. J. Fromont, SCUBA.

**Other Material**

**Diagnosis**
This species is distinctive from all other species of *Caulospongia* in having a fan-shaped morphology with a solid basal stalk. Ectosomal spicule brushes extend beyond the surface in a palisade. The skeletal arrangement remains identical to typical lobed species of *Caulospongia*.

This species does not have lobes or a reticulate branching structure which is found in other species of *Caulospongia*.

**Description**
*Shape*: These sponges are erect fans, commonly bilobed, with basal stalks (Figure 10d, e). Specimens may have additional lobes on the outer surface, either as irregular raised ridges, <1 cm high, as seen in QM G311044, or as long fingerlike lobes seen in the holotype (Figure 10d).

*Dimensions*: Specimens are 9–40 cm tall with a stalk 4.5–12 cm long. The fans are 8.5–24 cm wide and split into two lobes approximately 6–8 cm above the stalk. Some of the specimens are pieces only.

*Colour*: WAM Z267 and Z268 pale peach–orange with slightly more yellow-orange interior, QM G311009 pale pink, QM G310451 pinkish white, QM G311044 peach/pink alive, in alcohol cream to beige or fawn.

*Texture and surface characteristics*: Firm, compressible. Surface porous with an adherent dermal membrane. Oscules visible on the edges of the fans and lobes, small pores <1 mm wide, abundant on outer side of fan.

*Ectosomal and subectosomal*: Spicule fans and a layer of parallel spicules overlying these form a thick surface skeleton. The parallel layer of spicules is 140 μm wide and is dense and compact. The sharp end of the spicule fans protrude beyond the parallel layer by 50–100 μm and form a palisade.

*Choanosomal*: Beneath the ectosomal layer the primary fibres spread into wide fans or brushes and below this region fibre development occurs (Figure 11d, e). It is a reticulate fibre skeleton becoming more plumoreticulate centrally, where the thickest fibres are oriented parallel to the surface. Primary fibres are 150–180 μm wide centrally cored by ~12 spicules. Secondary fibres are 30–50 μm wide cored by 1–5 spicules. Interstitial spicules present. The skeleton is dense.
and compact compared to other species of *Caulospogia* (Figure 11d, e).

**Megascleres:** (Figure 14). Tylostyles with flattened nail heads to bulb and stylole modifications. Spicules gently curved and thickest centrally along length. See Table 9 for spicule dimensions.

**Remarks**

The wide geographic distribution of the specimens examined may indicate a future separation into distinct species.

**Habitat Description**

Vertical or horizontal limestone reef with a component of either coral or kelp.

**Associated Fauna**

Barnacles within sponge tissue visible by small apertures and slightly raised surrounding surface. Ophuroids on the surface.

**Etymology**

This species is named for the bilobed fan shaped external morphology. From the Latin bi: two; flabellum, fan-shaped.

### DISCUSSION

This is the first work redescribing species of the genus *Caulospogia* since Topsent’s (1932) revision of Lamarck’s collections. *Caulospogia* flabellata, C. perfoliata and C. amplexa comprise "typical" morphotypes of the genus with circumvolving lobes around a hollow central stem and with a solid basal stalk. This morphology is consistent with the first description of the genus by Saville Kent (1871). The remaining four species described in this paper do not have this characteristic lobed morphology. C. venosa has lobes that are thick, perforated, and have dendritic veins, which is a very different morphology from the "typical" species. C. reticulata has lobes but there is a tendency for a reticulation to form between the lobes. C. biflabellata does not have lobes but has a double fan shape, and C. elegans has a reticulate branching morphology. The tendency to reticulation in *C. reticulata* is transitional between the lobed species and the interconnected branching morphology of *C. elegans*, the latter previously assigned to *Plectodendron*. This morphological gradation between species that were originally placed in separate genera supports the retention of the synonymy of *Plectodendron* with *Caulospogia*.

Recognition of a diversity of morphotypes, not previously included in the genus, but which otherwise have identical skeletal characters, necessitates broadening the generic definition of *Caulospogia*. Species of this genus have few skeletal characters but they consistently have the following attributes: one type of megasclere in a single size category, no microscleres, and no localisation of spicule categories within the skeleton. All the species described have surface brushes of tylostyles with a layer of tylostyles, parallel to the surface, overlying the brushes. The choanosomal skeleton always contains fibre cored by tylostyles. Some variation between species is apparent in the thickness of the parallel layer of spicules, the density of the spicules within the surface brushes, the proximity of the brushes to each other, and the degree of fibre development internally.

There are two possible explanations for the diversity of morphotypes found within this genus. One is that there is a single species with extreme variation in external morphology that occurs over a lengthy latitudinal gradient (Northern Territory border along the west and south coasts of Australia to New South Wales). The second is that the morphological characteristics are indicative of fixed differences at the species level. The first explanation was rejected when the phenotypic differences were found to be consistent and invariant. These morphological features identify a suite of sibling species defined by a range of phenotypic characters, primarily their consistently recognisable external growth forms. Differences were also noted in membrane development, thickness of the sponge lobes, and sizes of the spicules (Table 10). *C. flabellata* is characterised by narrow lobes with frilled edges, a fine adherent surface membrane, thin lobes and medium sized spicules; *C. pennatula* has very wide leafy lobes, a fine adherent surface membrane, thin porous lobes and long spicules; *C. perfoliata* has irregularly shaped thick lobes, a thick membrane, and medium sized spicules; *C. amplexa* has thick regular lobes, a detachable membrane and long thick spicules; *C. biflabellata* has a fan shaped morphology and long spicules, while *C. venosa* and *C. reticulata* have veined lobes and interconnected lobes respectively, and both species have thin spicules.

For some marine phyla the endemic component of the southwestern Australian fauna has been
Table 10 Characteristics of the species of Caulosponia.

<table>
<thead>
<tr>
<th>Species</th>
<th>Growth form</th>
<th>Membrane</th>
<th>Lobes</th>
<th>Spicule size (mean)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. plicata</td>
<td>narrow lobes with frilled edges</td>
<td>thin adherent</td>
<td>thin, faintly porous</td>
<td>153–199 µm long, 5.8–7.7 µm wide</td>
<td>North of Port Hedland to Shark Bay</td>
</tr>
<tr>
<td>C. pennatula</td>
<td>wide leafy lobes</td>
<td>thin adherent</td>
<td>thin porous</td>
<td>180–215 µm long, 5.9–9.0 µm wide</td>
<td>Carnavon to Abrolhos</td>
</tr>
<tr>
<td>C. perfoliata</td>
<td>thick irregular lobes</td>
<td>thick adherent</td>
<td>thick, slope upwards</td>
<td>166–197 µm long, 4.9–7.9 µm wide</td>
<td>Perth coast to Fitzgerald River</td>
</tr>
<tr>
<td>C. amplexa</td>
<td>thick regular lobes</td>
<td>thick, detachable</td>
<td>thick, slope downwards</td>
<td>171–220 µm long, 5.4–10.0 µm wide</td>
<td>Bonaparte Archipelago to Abrolhos</td>
</tr>
<tr>
<td>C. venosa</td>
<td>thick irregular lobes</td>
<td>thick adherent</td>
<td>thick, veined</td>
<td>180 µm long, 4.6 µm wide</td>
<td>Spencer Gulf, Shl. Aust.</td>
</tr>
<tr>
<td>C. reticulata</td>
<td>lobes with reticulation</td>
<td>thick, adherent</td>
<td>thick, connected</td>
<td>172–194 µm long, 4.5–7.2 µm wide</td>
<td>Capel River to Gulf of St. Vincent, SA</td>
</tr>
<tr>
<td>C. biflabellata</td>
<td>fan shape</td>
<td>thick, adherent</td>
<td></td>
<td>182–222 µm long, 6.7–8.6 µm wide</td>
<td>North West Cape to Albany</td>
</tr>
</tbody>
</table>

reported to have affinities with the southern Australian fauna (Hooper and Lévi 1994), and some authors suggest a ‘Western Australian Province’ may occur on this coastline (Knox 1980). To date, species of the genus Caulosponia have only been collected from Australian seas, and predominantly from Western Australia. Only two species, C. elegans and C. venosa have distributions that do not extend into Western Australian state waters; C. elegans is reported from Broughton Island and Pt. Jackson in New South Wales and C. venosa from Spencer Gulf in South Australia. The biogeographic implications of these distribution patterns are interesting, but prior to concluding that Caulosponia is indigenous to Western Australia with incursions and subsequent speciation in southern and eastern seas, further collections from adjacent waters must be made.

A Western Coast Overlap Zone between the tropical fauna of the Northern Australian tropical province and the Southern Australian Warm temperate province, is thought to be a region of transition of species with a gradual replacement of a tropical fauna in the north by a predominantly temperate fauna in the south (Wilson and Allen, 1987). In this study, none of the North Western species occur further south than the Abrolhos Islands and the southern C. perfoliata is not found further north than the Perth metropolitan coastline (Figure 15). It is not yet known if these distributions are an artifact of the limited collecting undertaken on the species to date, or whether there is some zone of transition between the northern and southern species between the latitudes of Perth and the Abrolhos.

The exception to species with either a northern or southern location is the distribution of C. biflabellata. Few specimens of this species have been collected but presently its distribution extends from North West Cape in the northwest to Albany in the southwest (Figure 15). This distribution may be influenced by the south flowing Leeuwin current moving along the Western Australian coastline which enables many tropical species to colonise southern localities such as Rottnest Island off the Perth metropolitan coastline (Morgan and Wells, 1991). Alternatively, this may be a composite species that with future collecting will be split into geographically separated species. There is emerging evidence that species of giant clams formerly thought to have a widespread Indo-Pacific distribution may be instead a number of cryptic species each with a more restricted range (Benzie and Williams, 1997). Only further collection of the Caulosponia species within Western Australian waters will assist in resolving the
Australian species of Caulospoigia

Figure 15 Map of Australia showing the locality of the specimens examined in the study.

did not define geographical boundaries of the species as defined in this paper.

Within species of Caulospoigia it is possible that populations may have patchy distributions. For example, only one specimen of C. amplexa was seen at the Abrolhos during a dive of one hour duration (0-20 m), but when collecting in Albany, C. biflabellata was one of the most common sponges encountered, with a specimen recorded approximately every 2 metres on the reef edge during a dive of similar duration (depth 0-10 m) (J. Fromont, unpub. observ.).

The almost complete reliance in this study on preserved Museum material, and therefore the determination of species solely on morphological and skeletal characters of preserved sponges, has highlighted the great need for the continuing use of additional data sets in sponge taxonomy as previously suggested by other authors (e.g. Bergquist 1978; Bavastrello et al. 1994). Such data sets include chemotaxonomy, molecular systematics, enzyme electrophoresis, cytology and reproductive biology, statistical analyses of skeletal characters, as well as reliable ecological data and field descriptions. These alternative characters can be essential in the determination of species boundaries and relationships at generic and higher taxonomic levels.

As more material of the genus Caulospoigia is collected and preserved using alternative methods, other characters will be examined and applied to the systematics of this group of sponges. There is a need to supplement field descriptions and gather ecological data for each species, and to analyse their biogeographical distributions.

One of the first tasks when frozen material is available will be to examine the chemistry of the species for the presence of the sterol aaptamine.
Bergquist et al. (1991) reported the occurrence of aaptamine from Aaptos aaptos and a species of Suberites, and suggested that this may be a taxonomic marker for sponges within the family Suberitidae. To date it is not known whether or not this compound occurs in Caulospumia.

Genetic studies have been particularly useful in separating closely related species. Enzyme electrophoresis (Sole Cava et al. 1991) and molecular studies (Kelly Borges et al. 1991) have both assisted with species determinations and higher order systematics respectively. Similar studies should be undertaken on species of Caulospumia once new material is collected.

Skeletal differences can be influenced by environmental conditions. Palumbi (1986) examined sponges of the same species and found that specimens from high wave force habitats had spicule sizes and content that were greater than those from low wave force habitats. In this study, C. biflabellata had high spicule content with a thick parallel layer of surface spicules and dense spicule brushes. Collection of specimens of this species from within the same habitat and from other locations would allow for statistical comparisons of spicule size and degree of silification of the skeleton. In turn this would determine if these factors varied between specimens from different localities, or if this species was characterised by a dense skeleton irrespective of environmental factors.

Some of the species in this study have overlapping distributions, such as the North Western species C. pinnatula, C. plicata, and C. amplexa (Figure 15). If more than one species is found at a locality in reasonable numbers, then examination of their reproductive biology will assist with the determination of species boundaries. Studies of reproduction in sympatric species of Xestospongia demonstrated reproductive isolation by differences in timing of the spawning events, and reinforced the morphological distinctions that separated the species (Fromont and Bergquist 1994).

In summary, this study differentiated eight species of Caulospumia on the basis of consistent morphological characters. The identification of a species of Caulospumia with interconnecting nodes supported the synonymy of the genus Plectedendron (established for a sponge with reticulate branches) with the genus Caulospumia (established for species with circumvolving lobes). On the basis of spicule complement and skeletal characters examined here the location of the genus within the family Suberitidae is confirmed. Future studies will examine biochemical, reproductive, molecular and genetic characters of this genus and confirm the morphological systematics presented here.

ACKNOWLEDGEMENTS

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Australian species of Caulospongia


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Unusual new water mites (Acari: Hydracarina) from Australia, Part 1

Mark S. Harvey
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Abstract – The following new water mites are described from Australia: Austrolimnochares gen. nov. (Limnochiridae: Rhyncholimnochirinae), with the type and only included species Paralimnochares womersleyi Lundblad from southeastern Australia; Pontarachna ottoi sp. nov. (Pontarachnidae) from northeastern Australia; Thryptatus gen. nov. (Aturidae: Notoaturninae) for T. bouhouni sp. nov. (type species) from northeastern New South Wales and T. abnormis sp. nov. from southwestern Australia; Austromomonia gen. nov. for A. groionsae sp. nov. (Momoniidae: Momoniinae) from northeastern New South Wales; Hesperomononia gen. nov. (Momoniidae: Momoniinae) for H. humphreysi sp. nov. from Western Australia; and Tiranideopsis lecius sp. nov. (Mideopsidae: Mideopsinelinae) from northwestern Australia. Most of the described taxa represent groups with Gondwanan origins and most were collected from rheophilic or hyporheic habitats.

INTRODUCTION

The water mite fauna of Australia is quite well known at the familial and generic levels, thanks largely to the work of Cook (1986) who named numerous taxa and established a benchmark in our knowledge of the hydracarian fauna of the continent. Although additional genera have since been added, most specimens submitted to me for identification are readily attributable to a described genus. However, some recently collected specimens cannot be so easily placed, and either belong to demonstrably new genera or to genera that have not yet been recorded from Australia. The purpose of this paper is to provide names for several genera and species recently discovered in collections. These names are required to facilitate the completion of a key to Australian water mite families and genera currently being produced by the author.

Specimens are lodged in the Western Australian Museum, Perth (WAM), the Museum of Tropical Queensland, Townsville (MTQ) and the Australian Museum, Sydney (AM) and have been mounted on slides in Hoyers fluid. Most nomenclature follows Cook (1974), with the exception of the pedipalp and leg segments which follows Harvey (1996).

SYSTEMATICS

Family Limnochiridae Grube
Subfamily Rhyncholimnochirinae Lundblad

Remarks
The limnochirid subfamily Rhyncholimno-
With the removal of the Australian species from *Rhyncholimnochares*, there seems to be little support for the retention of the subgenus *Paralimnochares* which now contains two species, *R. surrysiiuhians* Lundblad 1937 [redescribed by Lundblad (1941)] from Brazil and *R. mexicana* Cook 1980 from Mexico. As noted above, *Paralimnochares* differs from the nominate subgenus only by the size and position of the pedipalpal tarsus which is slightly longer than broad and situated somewhat distally on the tibia. These features appear to be plesiomorphic when compared with *Rhyncholimnochares* in which the tarsus is reduced even further in size, often to a small nubbin bearing one or more terminal setae. The latter, apomorphic condition appears to render *Paralimnochares* paraphyletic and there seems to be little to recommend the retention of two separate subgenera within the genus. However, synonymy of *Paralimnochares* should be undertaken in conjunction with a broader review of the American rhyncholimnocharines, which is beyond the scope of the present study.

**Genus Austrolimnochares gen. nov.**

**Type Species**

*Paralimnochares womersleyi* Lundblad 1952.

**Diagnosis**

*Adult*

Idiosoma with long, tubular extension bearing the capitulum; without dorsal platelets. Pedipalp: femur-patella curved dorsally, sometimes partially fused with tibia; tarsus several times longer than broad. Mouth opening dorsally, surrounded by ring of setae. Ocular plate with 4 pairs of setae, 2 pairs on anterior protuberance, and 2 pairs just behind posterior eyes. Excretory pore not surrounded by sclerotised ring. Legs without swimming setae; claws simple.

**Remarks**

The two genera of Rhyncholimnocharinae can be distinguished by the following key:

1. Pedipalpal femur-patella curved dorsally, sometimes partially fused with tibia; pedipalpal tarsus several times longer than broad .......................... *Austrolimnochares* gen. nov.

Pedipalpal femur-patella straight; tibia and tarsus apparently fused; pedipalpal tarsus much reduced, only slightly longer than broad ........................ *Rhyncholimnochares* Lundblad

**Etymology**

The generic name is derived from the Latin stem *Austro* for south, and the generic name *Limnochares*. Gender: feminine.

* Austrolimnochares womersleyi (Lundblad), comb. nov.

*Paralimnochares womersleyi* Lundblad 1952: 23, figs 1, 2a–e; K. Viets 1956: 46.


*Rhyncholimnochares womersleyi* (Lundblad): Harvey 1990a: 490–492, figs 9, 18–25.

**Material Examined**

In addition to those specimens examined by Lundblad (1952), Cook (1986) and Harvey (1990a), the following can be added:

**Australia: Tasmania:** 1 adult, Baldy Creek, headwater region, Buckland Military Training Area [GR 656993], 15 April 1991, P. Horwitz (WAM).

**Remarks**

*Austrolimnochares womersleyi* inhabits streams and rivers in southeastern Australia including Tasmania, and has been collected as far north as southern Queensland (Harvey 1990a, figure 9). This species has been described and illustrated by Lundblad (1952), Cook (1986) and Harvey (1990a).

**Family Pontarachnidae Koenike**

**Genus Pontarachna Philippi**

*Pontarachna* Philippi, 1840: 191.

**Type Species**

*Pontarachna punctulum* Philippi, 1840, by monotypy.

*Pontarachna ottoi* sp. nov.

**Figures 1-8**

**Material Examined**

*Holotype* 

♂, Magnetic Island, Queensland, Australia, 19°08'S, 146°50'E, 2 March 1997, coral sand, J.C. Otto (MTQ).

**Diagnosis**

*Adult male*

Genital field with fully sclerotised ring bearing 21 setae mostly in anterior half; gonopore situated sub-posteriorly; pedipalpal tibia elongate, 6.8 times longer than deep.
New water mites from Australia

Description

Adult male

Integument soft, dorsalia, dorsal shield and ventral shields lacking; venter with several pairs of glandularia, as well as a pair of 'acetabula' (sensu Cook 1996) set in heart-shaped platelets situated posterolaterally to genital field; excretory pore situated terminally and without associated sclerotisation. Coxae (Figure 1) finely pitted; coxae fused on their respective sides, but completely separated medially; medial margin of coxa I slightly rounded and irregularly crenulate; suture line between coxae I and II not extending to posterior margin of coxae; suture lines between coxa II and III not reaching medial margin of coxae; coxa line between coxa III and IV extending onto narrow curved apodemes; coxa IV with lateral apodeme extending posteriorly from posterolateral corner of coxa IV, terminating in small 'club'; ventroglandularium I situated on posterior margin of coxa II. Genital field (Figure 3): with fully sclerotised ring bearing 21 setae mostly situated in anterior half; gonopore situated sub-posteriorly; 'acetabula' (sensu Cook 1996) apparently absent. Capitulum (Figure 2): chelicer styliform. Pedipalp (Figure 4): femur and patella each with single, acuminate disto-dorsal setae; tibia gently curved and elongate, 6.8 times longer than deep and 2.11 times longer than patella. Legs (Figures 5-8):

Figures 1–8 Pontarachna ottoi sp. nov., holotype ♂: 1, ventral; 2, capitulum and chelicerae; 3, genital field; 4, right pedipalp; 5, right leg I; 6, distal segments of right leg II; 7, distal segments of right leg III; 8, distal segments of right leg IV.
ventral setae of tibiae and metatarsi I long; all tarsi with dorso-distal pointed process and with concave ventral margins; swimming hairs present on legs III and IV, distributed as follows: tibia III, I; metatarsus III 2; tibia IV 1; metatarsus IV 2; claws of all legs of similar size, and with ventral clawlets.


Remarks
Pontarachna ottoi most closely resembles P. capensis Lohmann which was described from Simonstown, Cape Province, South Africa (Lohmann 1909), especially in the morphology of the male genital field (see Walter 1925: fig. 16) and the elongate pedipalpal tibia (see Walter 1925: fig. 14). In both species the male genital field bears approximately 20 setae situated on a sclerotised ring and the gonopore is usually situated close to the posterior edge of the genital field. In all other Pontarachna species the male genital field bears more than 25 setae and the gonopore is either central or anteriorly situated. Both P. capensis and P. ottoi possess an elongate pedipalpal tibia which is more than two times longer than the patella and is more than six times longer than deep.

Pontarachna ottoi differs primarily from P. capensis in the morphology of the pedipalpal tibia, which is 6.8 times longer than deep in the South African species and 6.0 times longer than deep in the Australian species.

Etymology
The specific epithet honors Jürgen Otto, collector of the holotype.

Family Aturidae Thor
Subfamily Notoaturinae Besch
Genus Thryptaturus gen. nov.

Type Species
Thryptaturus boultoni sp. nov.

Diagnosis
Adult
Dorsal shield divided into 12 platelets, with paired antero-medial platelet (bearing postocularia), posterior platelet (bearing 3 pairs of glandularia), a small central platelet, and 4 pairs of lateral platelets (3 of these bearing glandularia). Pedipalpal femur with or without ventral projections; tibia somewhat expanded, with paired ventral setae placed medially. Posterior margin of coxa IV transverse.

Description

Adult
Colour generally pale. Lateral and median eyes present as subcuticular black spots, but reduced in size. Dorsal and ventral shields present. Dorsal shield divided into 12 platelets, with paired antero-medial platelet (bearing postocularia), posterior platelet (bearing 3 pairs of glandularia), a small central platelet, and 4 pairs of lateral platelets (3 of these bearing glandularia). Ventral shield entire; coxae without parallel, longitudinal ridges; posterior margin of coxa IV transverse. Genital field bearing several pairs of acetabula, these borne on lateral margin of ventral shield in male and medially in female; male genital field cleft medially and somewhat setose. Pedipalps: femur with or without ventral projections; tibia somewhat expanded, with paired ventral setae placed medially.

Remarks
Thryptaturus differs from all previously described members of the Notoaturinae by the division of the dorsal shield into 12 platelets (Figures 9, 16), which has been largely achieved by the division of the antero-lateral platelet into three smaller platelets, and the addition of a small central platelet which lacks glandularia. The only other notoaturine with one or more central platelets is Notoaturus Besch from South America (Cook 1988) which differs from Thryptaturus in the possession of a pair of glandularia on this platelet. Despite the possession of 12 platelets in the dorsal shield, the genus still conforms to the general pattern found in most of the Australian Notoaturinae, as outlined by Cook (1986).

It further differs from other notoaturines in the morphology of the male genital field which is cleft medially, with the acetabula situated on the lateral margins of the genital field (Figure 11).

Etymology
The generic name alludes to the dorsal shield which is divided into numerous platelets (thurto, Greek, break) and is combined with the stem genus Aturus. Gender: masculine.

Thryptaturus boultoni sp. nov.

Material Examined
Holotype
♂, Never Never River, Tallowood Road turnoff,
Figures 9-15  Thryptaturus boultoni sp. nov., holotype ♂, unless state otherwise: 9, dorsal shield; 10, ventral shield; 11, genital field; 12, genital field, paratype ♀; 13, pedipalp; 14, left leg I, without trochanter; 15, left leg IV.
New South Wales, Australia, 30°21′41″S, 152°54′14″E, 30 cm deep well, 21 November 1997, J. Foster, P. Lisle, A. Boulton (AM).

**Paratype**

Australia: New South Wales: 1 ♀, same data as holotype except hyporheos #4, 4 October 1997, A. Boulton, J. Grown (AM).

**Diagnosis**

*Thryptaturus boultoni* differs from *T. abnormis* in its larger size (dorsal shield of *T. boultoni* 400 μm (♂), 415 μm (♀), vs. ♀ *T. abnormis* 358 μm), the very narrow median platelet, possession of lateral conical protuberances on the ventral shield, and the slightly different positions of the dorsoglandularia.

**Description**

Adult

Dorsal shield (Figure 9) divided into 12 platelets, with paired antero-medial platelet (bearing postocularia), antero-lateral platelet divided into a postero-lateral platelet, a postero-medial platelet and a small central platelet. Dorsal shield with 6 pairs of glandularia distributed as follows: 1 pair on antero-lateral platelet, 1 pair on lateral platelet, 1 pair on postero-lateral platelet, and 3 pairs on postero-medial platelet. Lateral and median eyes present as subcuticular black spots, but greatly reduced in size. Ventral shield (Figure 10): glandularium vgL situated near posterior margin of coxa II; coxae without parallel, longitudinal ridges; posterior margin of coxa IV transverse; openings of leg IV covered by small ventral lobes; posterior margin with several projections; lateral conical protuberances present. Genital field of male (Figure 11) terminally situated and cleft medially; bearing several pairs of acetabula situated on lateral margin of ventral shield; several pairs of setae situated medially. Genital field of female (Figure 12) subterminal; bearing 8–10 pairs of acetabula situated medially on ventral shield. Capitulum not unusual; chelicera 2 segmented. Pedipalp (Figure 13): femur with several small ventral projections; patella without small rounded ventral projection; tibia somewhat expanded, with paired ventral setae placed medially. Legs (Figs 13–14): without swimming setae; claws with small ventral clawlets.

Dimensions (mm), holotype ♂ (paratype ♀):


**Remarks**

*Thryptaturus boultoni* has been collected from a single stream in northeastern New South Wales.

**Etymology**

The specific epithet is in honor of Andrew Boulton for his endeavors in understanding hyporheic ecosystems.

*Thryptaturus abnormis* sp. nov.

**Material Examined**

Holotype

♀, Carey Brook, Western Australia, Australia, 34°22′03″S, 115°56′00″E, July 1993, K. Trayler (WAM 97/3151).

**Diagnosis**

Adult female

*Thryptaturus abnormis* differs from *T. boultoni* in its smaller size (dorsal shield of ♀ *T. abnormis* 358 μm, vs. ♂ *T. boultoni* 400 μm), the shape of the median platelet, lack of lateral conical protuberances on the ventral shield, and the slightly different positions of the dorsoglandularia.

**Description**

Adult female

Dorsal shield (Figure 16) divided into 12 platelets, with paired antero-medial platelet (bearing postocularia), antero-lateral platelet divided into a postero-lateral platelet, a postero-medial platelet and a small central platelet. Dorsal shield with 6 pairs of glandularia distributed as follows: 1 pair on antero-lateral platelet, 1 pair on lateral platelet, 1 pair on postero-lateral platelet, and 3 pairs on postero-medial platelet. Lateral and median eyes present as subcuticular black spots, but greatly reduced in size. Ventral shield (Figure 17): glandularium vgL situated near posterior margin of coxa II; coxae without parallel, longitudinal ridges; posterior margin of coxa IV transverse; openings of leg IV covered by small ventral lobes. Genital field (Figure 19) subterminal; bearing 9 pairs of acetabula situated on ventral shield. Capitulum not usual; chelicera 2 segmented. Pedipalp (Figure 18): femur without ventral projections; patella with small rounded ventral projection; tibia somewhat
Thryptatus abnormis sp. nov., holotype
without trochanter; 19, genital field.

Expanded, with paired ventral setae placed medially. Legs: without swimming setae; claws with ventral clawlets.


Remarks
Thryptatus abnormis has been collected from a stream in southwestern Australia, and is currently known from only a single specimen. This specimen is very pale, and the absence of setae associated with the dorsoglandularia could not easily be explained. Further specimens are required to determine the position of these setae.

Etymology
The specific epithet refers to the unusual dorsal shield (abnormalis, Latin, departing from the rule).

Family Momoniidae K. Viets
Subfamily Momoniinae K. Viets
Genus Hesperomomonia gen. nov.

Type Species
Hesperomomonia humphreysi sp. nov.

Diagnosis
Adult
Dorsal shield divided into equal-sized anterior and posterior platelets (Figures 20, 22). Dorsoglandularia lacking the gland bearing portion of the glandularia (Figures 20, 22). Ventral shield of males and females undivided (Figures 21, 23). Genital field bearing 3 pairs of acetabula, these borne in gonopore of male (Figure 26), and borne on small plates on either side of gonopore of female (Figure 27).

Description
Adult
Colour generally pale. Eye-spots present but
greatly reduced. Dorsal and ventral shields present. Dorsal shield divided into anterior and posterior platelets of approximately equal size; anterior platelet of dorsal shield bearing postocularia and 2 pairs of setae (lg2, dg3); posterior platelet bearing 3 pairs of setae (dg4, dg5, lg4); dorsal shield flanked by 4 pairs of lateral platelets, and 3 pairs of small platelets bearing glandularia (dg2, lg3, lg4), as well as 1 (d) or 3 (f) platelets which lack glandularia. Ventral shield entire in both sexes, with no evidence of suture lines; clear patch of integument present lateral to coxa IV. Coxal plates completely fused, with median suture lines obliterated. Glandularium vg1 situated on posterior margin of coxa II; vg2 situated posterior to coxa IV lateral to genital field. Genital field bearing 3 pairs of acetabula, these borne in gonopore of male, and borne on small plates on either side of gonopore of female. Pedipalps: tibia with 1 prominent ventral seta borne on prominent tubercle; tarsus with thick, claw-like terminal seta. Leg I with elongate claw-like terminal seta. Metatarsus, and highly modified tarsus I typical of the family.

Remarks

Cook (1974) recognised three subfamilies of Momoniidae, Momoniinae, Stygomomoniinae and Momonidinae, and a further two subfamilies, Cladomomoniinae and Cyclomomoniinae, were added by Orghidan and Gruia (1980, 1983) and Smith (1989a, 1989b), respectively. Smith (1989a) and Harvey (1990b) noted that the sole species of Cladomomoniinae, Cladomomonia mirifica Orghidan and Gruia from Cuba, lacks the synapomorphic character states of the Momoniidae and was effectively excluded from the family.

Of the four subfamilies currently recognised, three include only a single genus and the fourth, the Momoniinae, contains five genera: Mononia, Neomomonia, Astromomonia and Notomomonia; and ventral shield entire in both sexes, especially the female (plesiomorphy shared with Mononia and Partidomomonia).

These data seem to indicate that Hesperomomonia cannot be included in a clade which includes those momoniids with a female ventral shield which bears a separate platelet posterior to the genital field (Astromomonia, Cyclomomonia Smith, Mononia, Neomomonia, Notomomonia, Stygomomonia Szalay and Xenomomonia Orghidan et al.). Therefore, like Mononia and Partidomomonia, Hesperomomonia appears to belong to a plesiomorphic clade of Mononiidae. Although a direct relationship with Mononia is not apparent, it appears that Hesperomomonia and Partidomomonia share at least one apomorphy, the loss of the gland-bearing portion of some of the glandularia on the dorsal shield (see descriptions of Partidomomonia species in Cook 1983, 1986, 1992 and Harvey 1990b), and the two genera can be confidently placed as sister taxa. Indeed, the only feature which separates the two genera is the division of the dorsal shield into several platelets in Partidomomonia. Unfortunately, this leaves Hesperomomonia without any identifiable apomorphies but the cladistic analysis of the Momoniidae proposed by Smith (1989a, 1989b) may provide a suitable framework within which the status and position of the new genus can be adequately assessed.

Etymology

The generic name refers to the occurrence of the type species in Western Australia (hesperus, Latin, west) and is combined with the stem genus Mononia. Gender: feminine.

Hesperomomonia humphreysi sp. nov.

Figures 20-27

Material Examined

Holotype

♂, large (>1 km) pool in Fortesque River, at Fortesque River road bridge, Western Australia, Australia, 21°17.52'S, 116°08.23'E, Bou-Rouche pump, medium sample, 3 m, sample 4, 5 August 1997, W.F. Humphreys and S.M. Eberhard, BES 4982 (WAM 97/3149).

Paratype

Australia: Western Australia: 1 ♀, large (>1 km) pool in Fortesque River, at Fortesque River road bridge, 21°17.52'S, 116°08.23'E, Bou-Rouche pump, shallow sample, water edge, sample 5, 5 August 1997, W.F. Humphreys and S.M. Eberhard, BES 4962 (WAM 97/3150).
Figures 20–23  *Hesperonemonia humphreysi* sp. nov.: 20–21, holotype ♂: 20, dorsal shield; 21, ventral shield; 22–23, paratype ♀: 22, dorsal shield; 23, ventral shield.
Figures 24-27  *Hesperomonia humphreyi* sp. nov.: 24, metatarsus and tarsus I, holotype ♂; 25, right pedipalp, holotype ♂; 26, genital field, holotype ♂; 27, genital field, paratype ♀.

**Diagnosis**

*Adult*

As for genus.

**Description**

*Adult*

Dorsal and ventral shields present. Lateral eyes present, but extremely small. Dorsal shield (Figures 20, 22) widest sub-anteriorly; divided into anterior and posterior platelets of approximately equal size; anterior platelet bearing postocularia and 2 pairs of setae (lg2, dg3); posterior platelet bearing 3 pairs of setae (dg4, dg5, lg5); dorsal shield flanked by 4 pairs of lateral platelets, and 3 pairs of small platelets bearing glandularia (dg2, lg3, lg4), as well as 1 (♀) or 3 (♂) platelets which lack glandularia. Ventral shield (Figures 21, 23) entire; capitular bay deep and basally rounded; vg1 situated near posterior margin of coxa II; medial suture line obliterated but all coxal suture lines visible; medial margin of coxa IV broad; openings of leg IV covered by small ventral lobes; clear patch of integument present lateral to coxae IV; excretory pore situated closer to posterior margin of ventral shield than to genital field. Genital field (Figures 26, 27) bearing 3 pairs of acetabula, these borne in gonopore of male, and borne on small plates on either side of gonopore of female. Capitulum not unusual; chelicera 2 segmented. Pedipalp (Figure 25): all setae acuminate; tibia expanded ventrally, with 1 prominent ventral seta borne on prominent tubercle; tarsus with thick, claw-like terminal seta. Legs (Figure 24): metatarsus I tubular and much longer than all other segments of leg I; tarsus I highly modified with proximally directed claw; without swimming setae; all setae acuminate, except for some distal setae on leg IV, distributed as follows: patella (1), tibia (2), metatarsus (2); claws with ventral clawlets.

Dimensions (μm) ♂ (♀): dorsal shield 816/564 (830/545), ventral shield 920/696 (880/706). Genital field 64/49 (145/1.33). Pedipalp: trochanter 19 (21), femur 70 (68), patella 42 (47), tibia 77 (75), tarsus, excluding distal claw 41 (39). Leg I: trochanter 66 (61), femur 111 (96), patella 147 (150), tibia 148 (151), metatarsus 302 (309), tarsus 145 (142). Leg IV: trochanter 108 (103), femur 136 (134), patella 126 (127), tibia 173 (180), metatarsus 218 (222), tarsus 208 (211).

**Remarks**

*Hesperomonia humphreyi* was collected with the aid of a Bou-Rouch pump driven between large-
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cobbles from the edge of a large pool, some 1 km in diameter, in the Fortesque River. The mites came from relatively shallow or medium pump samples, and were not found in deeper samples collected at the same time (W.F. Humphreys, personal communication).

Etymology
The specific epithet honors Dr W.F. (Bill) Humphreys who collected the only known specimens.

Genus *Austromononia* gen. nov.

Type Species
*Austromononia grozonsae* sp. nov.

Diagnosis

*Adult female*

Dorsal shield present and divided into anterior and posterior platelets, with the anterior platelet significantly smaller than the posterior platelet; anterior platelet bearing postocularia; posterior platelet bearing glandularia dg3, dg4, dg5 and lg5; lg2 situated on separate triangular, antero-lateral platelet; lg4 situated in dorsal furrow. Ventral shield divided, with glandularia vg4 and vg5 situated on a separate posterior platelet, and vg3 situated on a separate postero-lateral platelet; lg1 and lg3 situated on lateral margins of ventral shield. Genital field bearing 3 pairs of acetabula borne on small platelets on either side of gonopore. Tarsus I with thickened proximal seta.

Description

*Adult female*

Colour extremely pale. Eye-spots present. Dorsal and ventral shields present. Dorsal shield divided into anterior and posterior platelets, with the anterior platelet significantly smaller than the posterior platelet; anterior platelet bearing postocularia; posterior platelet bearing glandularia dg3, dg4, dg5 and lg5; lg2 situated on separate triangular, antero-lateral platelet; lg4 situated in dorsal furrow. Ventral shield divided, with glandularia vg4 and vg5 situated on a separate posterior platelet, and vg3 situated on a separate postero-lateral platelet; lg1 and lg3 situated on lateral margins of ventral shield; clear patch of integument not present lateral to coxae IV; several short, curved setae present on coxa IV. Coxal plates with suture lines visible. Glandularium vg1 situated on posterior margin of coxa II; glandularium vg2 situated posterior to coxa IV anterior to genital field. Genital field bearing 3 pairs of acetabula, these borne on small plates on either side of gonopore. Pedipalps: tibiae with 2 prominent ventral setae borne on prominent tubercle; tarsi with 2 thick, claw-like terminal setae. Leg I with greatly expanded and stout metatarsus, and highly modified tarsus I typical of the family; tarsus I with thickened proximal seta.

Remarks

The generic placement of the Australian species described here is somewhat problematic due to the lack of males which often provide important phylogenetic data in the nature of the genital field. However, it is clear that the species shares many similarities with *Neomomonia* Cook from New Zealand, currently known from five species (Cook 1983, 1992; Schwoerbel 1984). These similarities include:

- dorsal shield divided into two platelets, with the anterior portion somewhat smaller than the posterior portion. The division represents an apomorphic character state shared with many other momoniid genera, including *Cyclomomonia*, *Hesperomomonia*, *Momonia*, *Partidomomonia*, *Notomomonia* and *Xenomomonia*. The small anterior platelet is elsewhere restricted to species of *Momonia*.
- glandularium lg2 situated on antero-lateral platelets. This is a plesiomorphy shared with *Momoniella*, *Partidomomonia* and *Cyclomomonia*.
- Small female acetabular platelets. This is an apomorphy restricted to *Neomomonia* and *Austromononia*.
- tarsus I with thickened proximal seta. This appears to be an apomorphy restricted to *Neomomonia* and *Austromononia*, but a similar seta may occur in *Notomomonia* (Cook 1988).

Despite these similarities, the two genera possess a number of differences:

- *Austromononia*: glandularium lg3 situated on ventral shield (probably a plesiomorphy shared with *Stygomomonia*). *Neomomonia*: glandularium lg3 situated in dorsal furrow (probably an apomorphy shared with most other genera).
- *Austromononia*: glandularium vg3 situated on separate postero-lateral platelet (autapomorphy). *Neomomonia*: glandularium vg3 situated on ventral shield (apomorphy shared with most other momoniid genera).

*Austromononia* further differs from *Neomomonia* in the lack of a clear patch of integument on the...
lateral margins of coxa IV. Although this may be considered sufficient grounds for the separation of separate genera, a precedent occurs in another momoniid genus, *Stygomomonia*, where a group of long setae may be present in some species but reduced to two pairs of short setae in others (Smith 1989b, 1989c). However, there is no doubt that considerable morphological differences separate *Austromomonia* and *Neomomonia*.

**Austromomonia grownsae** sp. nov.

*Figures* 28–32

**Material Examined**

**Holotype**

♀, Never Never River, Tallowood Road turnoff, New South Wales, Australia, 30°21'41"S, 152°54'14"E, 30 cm deep well, 21 November 1997, J. Foster, P. Lisle, A. Boulton (AM).

Figures 28–32. *Austromomonia grownsae* sp. nov., holotype ♀, unless stated otherwise: 28, dorsal shield; 29, ventral shield; 30, left pedipalp, paratype ♂; 31, left leg I; 32, left leg IV, without trochanter.
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Paratype


Diagnosis

Adult female

As for genus.

Description

Adult female

Colour extremely pale. Eye-spots present. Dorsal and ventral shields present. Dorsal shield (Figure 28) widest medially; divided into anterior and posterior platelets with the posterior platelet approximately twice the size of the anterior platelet; anterior platelet bearing postocularia only; posterior platelet bearing glandularia dg3, dg4, dg5 and lg5; dg2 situated on small anterior platelet in dorsal furrow; lg2 situated on separate triangular, antero-lateral platelet; lg4 situated on small lateral platelet in dorsal furrow. Ventral shield (Figure 29) divided; capitular bay deep and basally rounded; vg1 situated near posterior margin of coxa II; medial sutural line obliterated but all coxal suture lines visible; medial margin of coxa IV broad; openings of leg IV covered by ventral lobes; clear patch of integument not present lateral to coxae IV; 3 pairs of long setae on coxae IV; excretory pore situated at posterior margin of ventral shield. Genital field (Figure 29) bearing 3 small pairs of acetabula, tliese borne on small plates on either side of gonopore of female. Capitulum not unusual; chelicera 2 segmented. Pedipalp (Figure 30): all setae acuminate; tibia expanded ventrally, with 2 prominent ventral setae borne on prominent tubercle; tarsus with 2 thick, claw-like terminal setae. Legs (Figures 31, 32): without swimming setae; metatarsus I greatly expanded and stout; tarsus I modified as typical for family; tarsus I with thickened proximal seta; claws II-IV with ventral clawlets.


Remarks

The holotype was bearing a single, somewhat ovoid, egg.

Etymology

The specific epithet honours Jane Growns, enthusiastic student of Hydracarina.

Family Mideopsidae Koenike

Subfamily Mideopsellinae Lundblad

Remarks

Relationships within the Mideopsidae are poorly understood, and the generic and subfamilial classifications appear to be somewhat unreliable. Cook (1974, 1986) included five subfamilies within the family (Mideopsinae, Mideopsellinae, Guineaxonopsinae, Gretacarinae and Plaumanniinae). A sixth subfamily, the Phreatomideopsinae, was proposed by Schwoerbel (1986) but was subsequently placed in the synonymy of the Mideopsellinae by Cook (1988).

Five genera are currently included in the Mideopsellinae: Mideopsella Lundblad and Phreatomideopsis Schwoerbel from South America, Mideopsellides K.O. Viets from South Africa, Tiramideopsis Cook from India and Australia (see below) and Tillia Harvey from Australia (Cook 1967, 1974; Schwoerbel 1986; Harvey 1990c). The subfamily appears to have Gondwanan origins as all genera are restricted to the southern continents.

Phreatomideopsis was placed in a separate subfamily by Schwoerbel (1986) for a single rheophilic species from southern Chile, Phreatomideopsis arrenuripalpis Schwoerbel. He noted several unusual features of the species including the presence of lateral sclerites in the female gonopore and an uncate pedipalp, which he regarded as so unusual as to question the familial position of P. arrenuripalpis. As noted by Cook (1988), these features clearly ally Phreatomideopsis to Tiramideopsis from India, described by Cook (1967) for four species taken from interstitial sediments in the states of Mysore and Maharashtra.

Genus Tiramideopsis Cook

Tiramideopsis Cook 1967: 190.

Type Species

Tiramideopsis (Tiramideopsis) ovalis Cook 1967, by original designation.

Diagnosis

Adult

Dorsal shield present, entire and ovoid; U-shaped ridge present; with three pairs of glandularia. Pedipalp uncate. Deep genital bay situated between coxae IV; four or seven pairs of acetabula situated within gonopore; separate lateral sclerites within the female gonopore.

Remarks

Tiramideopsis appears to represent the sister-group to Phreatomideopsis from Chile, as both
Figures 33–38  *Tiramudeopsis* incus sp. nov., holotype ♀, unless stated otherwise: 33, dorsal shield, paratype ♂; 34, ventral shield, paratype ♂; 35, genital field, 36, left pedipalp; 37, left leg I; 38, left leg IV.
possess separate lateral sclerites within the female gonopore (Figure 35), an apomorphic character state within the Arrenuroidea. *Tiramideopsis* differs from *Phremotomeiosis* by the deep genital bay situated between coxae IV (Figure 34).

Cook (1967) divided the genus *Tiramideopsis* into two subgenera, *Tiramideopsis* (*Tiramideopsis*) and *Tiramideopsis* (*Navamideopsis*) based upon a number of apparently autopomorphic features found in the type species of the latter, *T. (N.) expansipes* Cook, including the presence of seven pairs of acetabula. The species described below can probably be assigned to *Tiramideopsis* (*Tiramideopsis*) but the lack of male specimens precludes a definitive placement.

_Tiramideopsis lictus_ sp. nov.
Figures 33–38

**Material Examined**

**Holotype**
♀, Palm Springs, Millstream aquifer, 21°34’44”S, 116°58’07”E, Western Australia, Australia, 30 July 1997, haul net in piezometer P4, W.F. Humphreys, S.M. Eberhard, BES 4876 (WAM 97/3223).

**Paratype**
Australia; Western Australia: 1 ♀, Millstream aquifer, 21°34’24”S, 116°57’59”E, 19 October 1996, haul net in piezometer P1, W.F. Humphreys, BES 4006 (WAM 97/3224).

**Diagnosis**

**Adult female**

Suture lines between coxae III and IV meeting at anterior margin of genital field. Four pairs of acetabula; each acetabulum large, but with extremely small cap; lateral genital sclerites with 2–4 pairs of small spines in posterior half.

**Description**

**Adult female**

Dorsal and ventral shields present. Lateral eye spots present; medial eye apparently absent. Dorsal shield (Figure 33) entire and ovoid, widest medially; bearing 3 pairs of sub-equidistant dorsoglandularia; dorsoglandularial setae situated close to glandularia; postocularia slightly anterior to anterior-most glandularia of dorsal shield. Ventral shield (Figure 34) entire; vgl 1 situated near posterior margin of coxa II; all coxal suture lines visible, those between III and IV meeting at anterior margin of genital field; posterior margin of coxa IV not visible; outer coxal margins with pointed tips; openings of leg IV not covered by small ventral lobes; capitular bay moderately deep and basally rounded, not extending far forward of ventral shield; excretory pore incorporated into ventral shield, situated midway between genital field and posterior margin of ventral shield. Genital field (Figure 35) placed within deep genital bay situated between coxae IV; with 4 pairs of large acetabula situated within field; each acetabulum with extremely small cap; gonopore with separate lateral sclerites; lateral genital sclerites with 2–4 pairs of small spines in posterior half. Capitulum and chelicera not unusual. Pedipalp (Figure 36) uncate; without setae except for two acuminate setae situated on patella, 2 small distal tibial setae, and 1 large tarsal thick seta. Legs (Figures 37, 38): leg I with long stiff ventral setae on femur (2), patella (1) and tibia (1); patella I–III with long sub-distal seta; without swimming setae; with very few serrate setae; claws with large ventral clawlets.


**Remarks**

In the possession of only four pairs of acetabula, *Tiramideopsis lictus* most closely resembles *T. (T.) ovalis* Cook, *T. (T.) tanasachiae* Cook and *T. (T.) pallida* Cook from India, but differs from all of them by the possession of 2–4 pairs of small spines on the lateral genital sclerites and by the extremely small acetabular caps.

**Etymology**

The specific epithet refers to the relictual nature of the Australian species, left behind in the southern hemisphere after the rafting of the Indian subcontinent during the early Tertiary (*lictus*, Latin, abandoned).

**ACKNOWLEDGEMENTS**

I wish to thank Andrew Boulton, Jane Growns, Pierre Horwitz, Bill Humphreys, Jürgen Otto and Kerry Trayler for access to the mites reported above.

**REFERENCES**


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A new genus of the water mite family Piersigiidae from Australia (Acari: Hydrachnidia)

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Abstract - A new genus from the water mite subfamily Piersigiinae and its sole new species, *Austrapiersigia montana*, are described from Victoria, Australia. It is the first record of this subfamily for the southern hemisphere.

INTRODUCTION

The water mite family Piersigiidae contains two distinct subfamilies, the Piersigiinae and the Stygolimnocharinae. The Piersigiinae, with the only genus *Piersigia* Protz, have been collected only in the Holarctic. Most of the four described species of this subfamily inhabit temporary water bodies or semi-aquatic habitats (Imamura and Mitchell 1967; Van Maanen et al. 1997). However, because of its reduced lateral eyes, *Piersigia crista* Mitchell might be an interstitial species (Cook 1974). The Stygolimnocharinae, with the genera *Stygolimnoclathus* Cook and *Parawandesia* E. Angelier, are known from India, Australia and Europe. The three known species of these genera live in interstitial habitats (Cook 1967, 1986; Gerecke and Cook 1995).

Utilising the Karaman-Chappuis method (see Schwoerbel 1979), an interstitial water mite belonging to the subfamily Piersigiinae was collected in Victoria. This is not only the first record of this subfamily for Australia, but also for the southern hemisphere. The species belongs to a new genus, and is described below.

MATERIAL AND METHODS

The material has been collected by the author. The holotype has been deposited in the Museum of Victoria, Melbourne.

Measurements of palp and leg segments are dorsal lengths. All measurements are in μm. The body length is measured dorsally from the unmouted specimen. The following abbreviations have been used: PI–PV palp segments 1–5; I–leg–5 fifth segment of first leg.

SYSTEMATICS

Family Piersigiidae Oudemans
Subfamily Piersigiinae Oudemans

Genus *Austrapiersigia* gen. nov.

Type Species
*Austrapiersigia montana* sp. nov.

Diagnosis
Characters of the subfamily Piersigiinae. Dorsum with two pairs of large plates medially and one large plate posteriorly, none of them encompassing glandularia.

Description
Lateral eyes in capsules, incorporated into an eye plate composed of two pairs of glandularia platelets and the pre- and postocularia platelets, loosely joined by sclerotized bridges. A clear area in the anterior part of the largest eye platelet might be a median eye. Glandularia sclerites partially surrounding the large glandularia. Dorsum medially with two pairs of large plates, and posteriorly with one large plate. Capitulum with a large circular mouth opening containing a frilled, wheel-like membrane. Coxal plates in four groups. Acetabula numerous, in four groups, surrounded by sclerotized rings. Acetabula shortly stalked. Excretory pore on a sclerite. PHI expanded laterally.

Remarks
The new genus shares many characters with the genus *Piersigia*, but differs noticeably in the arrangement of plates on the dorsum and the shape of PHI. All known *Piersigia* species have relatively large, rectangular lateroglandularia platelets which are lacking in *Austrapiersigia*, and have the other glandularia platelets more or less crescent shaped (as in *Austrapiersigia*). The dorsal plates of *Piersigia* are small, elongate and irregularly shaped, and those of *Austrapiersigia* large with rounded corners.

Etymology
The name of the new genus refers to its southern
Figures 1, 2  *Australosigma montana* sp. nov., holotype 9: 1, dorsal view; 2, ventral view. Scale line 200 μm.
A new genus of Piersigiidae

Figures 3-5 Austriapiersigia montana sp. nov., holotype 9: 3, lateral view of PII-PV; 4, dorsal view of PII-PIII; 5, I-leg-5-6. Scale lines 50 μm.
occurrence and the similarity with the genus *Piersigia*.

*Austrapiersigia montana* sp. nov.

Figures 1-5

Material Examined

**Holotype**

♀, interstitial of unnamed creek, The Long Plain (± 1300 m above sea level), Mt Buffalo National Park, Victoria, Australia, 10 October 1997.

Diagnosis

As for genus.

Description

**Female**

Body 1319 long and 980 wide. Integument soft, papillate, body colour orange. Posterior part of eye plate rounded, 242 long. This large plate with a clear area which might be a median eye. Dorsum medially with two pairs of large plates (Figure 1), the anterior 281 in width, the posterior 340-369 in width. Posterior plate of dorsum 582 in width. Coxal plates in four groups, covered with many fine setae. Genital field 218 in length. Acetabula shortly stalked, located in four groups (Figure 2), the anterior groups more elongated compared to posterior groups. Each group has 21–22 acetabula. Lengths of PI-PIV: 32, 94, 98, 70, 36. PIII with a group of setae at anteroventral corner (Figure 3), PIII greatly expanded laterally (Figure 4). Lengths of I-leg-4-6: 115, 156, 173. Lengths of IV-leg-4-6: 165, 194, 223. Legs with numerous stout, serrated setae (Figure 5); swimming setae absent, claws simple.

Etymology

The name refers to its occurrence in the mountains of the Dividing Range.

ACKNOWLEDGEMENTS

I am indebted to the Department of Natural Resources and Environment (Melbourne) for their permission to collect water mites in the national parks of Victoria and to Dr M.S. Harvey for his comment on a first draft of this paper.

REFERENCES


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A review of the Australasian species of *Anapistula* Gertsch (Araneae: Symphytognathidae)

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Abstract - The Australasian species of *Anapistula* Gertsch are revised and six species are recognised: *A. australia* Forster (Queensland), *A. troglobia* sp. nov. (Western Australia), *A. bifurcata* sp. nov. (Northern Territory), *A. jeraii* sp. nov. (Malaysia, Sarawak, Kalimantan and Krakatau Islands) and *A. tonga* sp. nov. (Tonga). *A. troglobia* and *A. cutucata* are the first known troglobitic species of the family Symphytognathidae and *Anapistula* is hypothesised to be the sister-group of the remaining symphytognathid genera. The male pedipalp of the type species, *A. secreta* Gertsch, is illustrated, and the systematic position of the only other New World species, *A. boneti* Forster, is discussed.

INTRODUCTION
The Symphytognathidae, as currently defined (Forster and Platnick 1977), contains five genera found in numerous tropical and southern temperate zones of the world. All genera have representatives in the New World but only *Curimagua* Forster and Platnick and *Globignatha* Balogh and Loks are restricted to this region. The remaining genera, *Symphytognatha* Hickman, *Patu* Marples and *Anapistula* Gertsch, are found in various other regions, such as Australia, New Guinea, islands of the Pacific and Indian Oceans, and Africa. Griswold (1987) postulated that *Symphytognatha* might be an ancient genus, and it seems probable that many other genera predate the breakup of Gondwana during the Cretaceous.

The genus *Anapistula* differs from all other symphytognathid genera by a low carapace and the retention of posterior spiracles (Forster and Platnick 1977), and currently contains six species with widely disjunct distributions: *A. secreta* Gertsch from central America (extending as far north as Florida and as far south as Colombia), *A. boneti* Forster from Mexico, *A. benoiti* Forster and Platnick from Zaire, *A. australia* Forster from southeastern Queensland, *A. caecula* Baert and Jocqué from Ivory Coast, and *A. seychellensis* Saaristo from the Seychelles (see Forster and Platnick 1977; Baert and Jocqué 1993; Saaristo 1996). The recent discovery of a remarkable troglobitic species from Western Australia (Harvey et al. 1993) has prompted a review of the Australasian species of *Anapistula*, the results of which are presented here. For comparative purposes, the two American species, *A. secreta* Gertsch and *A. boneti* Forster, are also illustrated and discussed.

The material discussed here is lodged in the American Museum of Natural History, New York (AMNH), Australian Museum, Sydney (AM), Australian National Insect Collection, CSIRO, Canberra (ANIC), C.L. Deeleman collection, Ossendrecht, Netherlands (CLD), Museum of Victoria, Melbourne (NMV), Northern Territory Museum, Darwin (NTM), Queensland Museum, Brisbane (QM) and Western Australian Museum, Perth (WAM). Terminology follows Forster and Platnick (1977), with the elements of the conductor discussed by Harvey (1992). All measurements are in mm.

SYSTEMATICS
Genus *Anapistula* Gertsch

*Anapistula* Gertsch 1941: 2; Forster and Platnick 1977: 21–22.

Type Species

*Anapistula secreta* Gertsch 1941, by original designation.

Diagnosis

Pars cephalica only slightly elevated. Posterior spiracles present. Six or four eyes present, sometimes reduced to indistinct spots; PME's usually absent; when present, adjacent, far removed from lateral eyes.

Remarks

The Symphytognathidae appear to be divisible into two groups, the first containing the sole genus *Anapistula* and the second containing the remaining genera, *Symphytognatha, Globignatha, Curimagua*.
and Patu). This division is based upon two character states:

The pars cephalica of all Anapistiila species is only slightly elevated; whereas it is strongly raised in all other symphytognathids (Forster and Platnick 1977) and in most members of other families currently postulated as putative sister-groups to the Symphytognathidae (Coddington 1990; Coddington and Levi 1991). Anapidae and Mysmenidae [e.g. see illustrations in Gertsch (1960) and Platnick and Forster (1989)]. The former groups to the Symphytognathidae (Coddington 1990). In all other symphytognathids (Forster and Platnick 1977) and in most members of other families currently postulated as putative sister-groups to the Symphytognathidae, noting that the limits of the family would require adjustment due to the unfused chelicerae, currently considered an apomorphy of the family (Forster and Platnick 1977). The nature of the posterior spiracles of the type species, A. lyrata Simon, are not yet known and its placement within the arrangement suggested above is currently untested. The two groups defined above may eventually deserve subfamilial status, once the position of Anapogonia is tested and ascertained.

With the addition of the five new species of Anapistiila described below, the genus now comprises 11 species, six of which are represented by males: A. secreta (Figure 1; Forster and Platnick 1977, p. 22), A. boneti (Figure 20; Forster 1958: p. 13), A. bifurcata, A. cuttacutta, A. jerai and A. longa (see below). Of interest is the relative uniformity of the pedipalp of five of these species (A. secreta, A. bifurcata, A. cuttacutta, A. jerai and A. longa), which possess a broad, triangular ventral element to the conductor (C1) which covers the embolus, and a somewhat spatulate dorsal element to the conductor (C2) with a large subdistal, circular depression (Figures 1, 6, 12, 15).

This pattern is not evident in the male holotype of A. boneti (examined, lodged in AMNH), in which the pedipalp, which is somewhat distorted due to permanent slide mounting, shows a number of anomalous features. These include a broad, heavily sclerotised and distally bifurcate ventral conductor element, and the lack of a spatulate central section of the dorsal conductor element which, in contrast, appears very small, lightly sclerotised and distally digitulate (Figure 20). In addition, the abdomen, which is higher than wide, bears a dorsal scute and a ventral, striated genitalic plate (Figure 21), the legs possess trichobothria, and the PME’s are present. It now appears that A. boneti should be excluded from the genus Anapistiila, but its true placement is uncertain and it may not even belong in the Symphytognathidae as all other symphytognathids lack pedal trichobothria (Forster and Platnick 1977). Gertsch (1960) transferred A. boneti to Iardinus Simon, previously known from only the type species, I. weyersi Simon from Sumatra, and described I. albulus Gertsch from South America. Forster and Platnick (1977) transferred I. albulus to the theridiid genus Stylosis Simon and returned A. boneti to Anapistiila. The final position of A. boneti should await further examination of the type, along with newly collected material including a female.

As noted by Forster and Platnick (1977) and Baert and Jocqué (1993), symphytognathids are amongst the smallest of all adult spiders, with males of Patu diina Forster and Platnick only 0.37 mm (excluding chelicerae). Baert and Jocqué (1993) record a total body length of 0.48–0.55 mm for females of Anapistiila caccula, and to this can be added A. bifurcata (males 0.48, females 0.52 mm in length) and A. jerai (male 0.41, female 0.48 mm in length). Females of the cave-dwelling species A. troglobia are 0.80 mm, the large size of which is typical of many troglobitic organisms which are often larger than their epigean counterparts.

![Figure 1](image-url)  
**Figure 1** Left pedipalp, retrolateral: 1, Anapistiila secreta Gertsch (♂ from Archbold Biological Station, Highlands County, Florida, U.S.A., AMNH). Abbreviations: C1, conductor, ventral element; C2, conductor, dorsal element; EM, embolus; MA, median apophysis.
Biogeography

It now seems clear that *Anapistula* is a tropical genus, with most members occurring in rainforest habitats, and with the most temperate locality situated at Camp Mountain, near Brisbane, Queensland. The sole exception to the rainforest habitat is *A. troglobia* which occurs in the humid caves of the semi-arid Cape Range, Western Australia. Many other troglobitic members of the Cape Range faunal community also seem to have been derived from tropical elements (e.g. Harvey *et al.* 1993; Humphreys 1993) which highlights the relictual nature of these cave systems.

Key to species of *Anapistula* Gertsch

**Males**

1. Ventral element of conductor (C1) basally very broad and abruptly tapering (Figure 15) .................. *Anapistula tonga* sp. nov. (Tonga)

2. Dorsal element of conductor (C2) distally bifurcate (Figure 6) or with lateral flange (Figure 1) .................................................. *Anapistula jerai* sp. nov. (Malaysia, Sarawak, Indonesia)

3. Dorsal element of conductor (C2) with large, distally acute, bifurcations (Figure 6) .............. *Anapistula bifurcata* sp. nov. (Australia, Northern Territory)

4. Dorsal element of conductor (C2) without distal bifurcations (Figures 1, 10) .................. *Anapistula cutlacutta* sp. nov. (Australia: Northern Territory)

Females

1. Femur I with a large retrolateral tubercle (Figure 5) .............. *Anapistula troglobia* sp. nov. (Australia: Western Australia)

2. Median epigynal duct not reaching to tip of spermathecae (Forster and Platnick 1977, fig. 74) .......... *Anapistula benuoi* Forster and Platnick (Zaire)

   Median epigynal duct reaching to tip of spermathecae (Figures 4, 9, 14, 19) ..................

Females

1. Femur I with a large retrolateral tubercle (Figure 5) .............. *Anapistula troglobia* sp. nov. (Australia: Western Australia)

   Femur I without retrolateral tubercles ............ 2

2. Median epigynal duct not reaching to tip of spermathecae (Forster and Platnick 1977, fig. 74) .......... *Anapistula benuoi* Forster and Platnick (Zaire)

   Median epigynal duct reaching to tip of spermathecae (Figures 4, 9, 14, 19) .................. 3

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Material Examined

**Holotype**

♀, Camp Mountain, Queensland, Australia [27°24′S, 152°52′E], 26 December 1956, ex litter on sand beside creek, T.E. Woodward (QM S104).

Diagnosis

*Anapistula australis* appears to be most similar to *A. secreta*, but females of the former differ by the T-shaped median epigynal duct (Figure 2).
Description

Female (Holotype)
See Forster (1959).

Remarks
Forster (1959, fig. 130) depicted the presence of a colulus in this species, but my detailed examination of the holotype reveals that a colulus is indeed absent, a character state that now appears invariant within the genus. No further material of this species has been detected in museum collections.

Anapistula troglobia sp. nov.
Figures 3–5


Material Examined

Holotype
♀, Cave C-15, Cape Range, Western Australia, Australia, 22°13'S, 113°59'E, 25 June 1989, M.S. Harvey (WAM 94/1829).

Paratypes
Australia: Western Australia: Cape Range: 1 ♀, Cave C-15, 28 June 1989, M.S. Harvey (WAM 94/1830); 1 ♀, Cave C-15, 13 August 1992, R. L’Heureux, W.F. Humphreys, R.D. Brooks (WAM 94/1833); 1 ♀, Cave C-167, 22°09'S, 114°00'E, 21 June 1991, D. Brooks (WAM 94/1834–1835); 2 ♀, Cave C-167, 30 July 1991, C. Rippon (WAM 94/1837–1838); 2 ♀, Cave C-126, 21°47'S, 114°10'E, 19 September 1988, S. Eberhard (AM KS21582).

Diagnosis
This species can be distinguished from all other symphytognathids by the subbasal retrolateral tubercle on femur I (Figure 5). Other important characters include the reduction of the eyes to indistinct spots (Figure 3) and the ovoid spermathecae (Figure 4).

Description
Female (Holotype)
Total length 0.80. Carapace 0.29 long, 0.24 wide, 0.13 high. Femur I 0.36 long. Colour entirely creamy-white, except for sclerotised internal genitalia. Carapace (Figure 3) with 8 setae, 4 on clypeus, 2 on eyes, and 2 on posterior ridge of pars cephalica; pars cephalica only slightly higher than pars thoracica; 4 indistinct eye spots present. Chelicerae fused only subbasally; distal lobe of fang furrow with 2 conical teeth. Sternum posteriorly truncate. Pedipalp absent except for coxa. Legs: femur I with 1 large and several small
sub basal retrolateral tubercles, and several setae sitting in prominent tubercles (Figure 5); all patellae with retrolateral protuberance containing patch of lyriform organs; all tarsal claws without teeth. Epigyne (Figure 4): spermathecae oval, connected to single T-shaped copulatory duct; bases of copulatory duct with anterior swelling; heavily sclerotised triangular apophysis absent. Posterior spiracles present. Colulus absent.

Remarks
Anapistula troglobia is known from only three caves in the karst-rich Cape Range, Western Australia (Harvey et al. 1993), and is clearly the most troglobitic symphytognathid so far recorded and is only the second recorded from caves. The first, Curiumagnia chapmani Forster and Platnick, was taken from the roost of guacharo birds in entrance chambers of Coy-Coy Cave, Venezuela (Forster and Platnick 1977) and does not appear to exhibit any extreme troglobitic tendencies. On the other hand, A. troglobia exhibits a number of troglomorphic features, including significant reduction of eyes, extremely pale colouration, and elongated legs. Of the seven troglobitic spiders recognised by Harvey et al. (1993) from the Cape Range karsts, A. troglobia is the smallest, yet one of the most troglomorphic.

The egg-sac of one female was observed on 28 June 1989; it consisted of two large eggs connected with some loose strands of silk.

Etymology
The specific epithet refers to the presence of this species in caves (Greek: trogl, hole; bios, life).

Anapistula bifurcata sp. nov.

Materials Examined

Holotype
♂, gorge to NE. of Mt Gilruth, Northern Territory, Australia, 13°02'S, 133°05'E, July 1979, rainforest, sieved litter, G.B. Monteith (QM S20801).

Paratypes
Australia: Northern Territory: 3 ♀, same data as holotype (QM S35044-35045); 1 ♀, same data as holotype (WAM 97/14).

Figures 6-9 Anapistula bifurcata sp. nov., holotype ♂: 6, left pedipalp, retrolateral, with detail of distal end of conductor; 7, left bulb, with conductor omitted, showing embolic duct; female paratype (QM S35044): 8, abdomen, ventral, showing spinnerets, spiracles and vulva; 9, epigyne, ventral.
Other Material
Australia: Northern Territory: 2 juveniles, same data as holotype (QM S35046).

Diagnosis
Males of this species differ by the shape of the dorsal element of the conductor (C2) which is distally bifurcate (Figure 6). Females cannot be separated from those of *A. jerafl, but differ from all other species by the following combination of characters: spermathecae spherical (Figure 9), median epigynal duct reaching to tip of spermathecae (Figure 9), and femur I 0.26 mm in length.

Description
Male (Holotype)
Total length 0.48. Carapace 0.26 long, 0.26 wide, 0.14 high. Femur I 0.29 long. Colour entirely pale yellow. Carapace apparently with 8 setae, 4 on clypeus, 2 on eyes, and 2 on posterior ridge of pars cephalica; pars cephalica only slightly higher than pars thoracica; 4 distinct eyes, surrounded by light pigment; PME completely absent. Chelicerae fused only subbasally; distal lobe of fang furrow with 2 conical teeth. Sternum posteriorly truncate. Pedipalp (Figures 6, 7): femur with tubercles on antero-ventral face; tibia without retrolateral apophysis; cymbium broad and cup-shaped, with hooked basal paracymbium; embolus coiled twice, embolic duct looped; median apophysis rounded; conductor comprising two discrete elements which enclose the embolus: ventral element (C1) basally broad and gradually tapering to a distal pointed projection; dorsal element (C2) distally bifurcate and with broad circular depression. Legs: femur I without tubercles; all patellae with retrolateral protuberance containing patch of lyriform organs; all tarsal claws without teeth. Posterior spiracles present. Colulus absent.

Female (Paratype QM S35044)
Total length 0.52. Carapace 0.25 long, 0.24 wide, 0.12 high. Femur I 0.26 long. Colour entirely pale yellow, except for sclerotised internal genitalia. Carapace with 8 setae, 4 on clypeus, 2 on eyes, and 2 on posterior ridge of pars cephalica; pars cephalica only slightly higher than pars thoracica; 4 distinct eyes, surrounded by light pigment; PME completely absent. Chelicerae fused only subbasally; distal lobe of fang furrow with 2 conical teeth. Sternum posteriorly truncate. Pedipalp absent except for coxa. Legs: femur I without tubercles; all patellae with retrolateral protuberance containing patch of lyriform organs; all tarsal claws without teeth. Epigyne (Figure 9): spermathecae spherical, connected to single T-shaped copulatory duct; bases of copulatory duct with anterior swelling; heavily sclerotised triangular apophysis present. Posterior spiracles present (Figure 8). Colulus absent.

Remarks
*Anapistula bifurcata* is known only from a single site lying outside the eastern border of Kakadu National Park, Northern Territory.

Etymology
The specific epithet refers to the bifurcate nature of the dorsal element of the conductor (*bifurcatus, Latin, split into two parts).

*Anapistula cuttacutta* sp. nov.

Material Examined

Holotype
$\delta$: Cutta Cutta cave, cave K-1, Northern Territory, Australia, 14°35'S, 132°25'E, 26 June 1994, W. Binks (NTM, transferred from WAM).

Diagnosis
Males of this species differ by the shape of the dorsal element of the conductor (C2) which bears a serrate process protruding from the distal margin (Figure 10).

Description
Male (Holotype)
Total length unknown. Carapace 0.26 long, 0.25 wide, height not measurable. Femur I 0.35 long. Colour entirely pale yellow. Carapaceal setae not observable; pars cephalica only slightly higher than pars thoracica; apparently without eyes. Chelicerae fused only subbasally; distal lobe of fang furrow with

Figures 10-11 *Anapistula cuttacutta* sp. nov., holotype $\delta$: 10, left pedipalp, retrolateral; 11, left bulb, with conductor omitted, showing embolic duct.
2 conical teeth. Sternum posteriorly truncate. Pedipalp (Figures 10, 11); presence of tubercles on femur not determined; tibia without retrolateral apophysis; cymbium broad and cup-shaped, with hooked basal paracymbium; embolus coiled twice, embolic duct looped; median apophysis rounded; conductor comprising two discrete elements which enclose the embolus; ventral element (C1) basally broad and gradually tapering to a distal pointed projection; dorsal element (C2) with a serrate process protruding from distal margin, and with broad circular depression. Legs: femur I without tubercles; all patellae with retrolateral protuberance containing patch of lyriform organs; all tarsal claws without teeth. Posterior spiracles present. Colulus absent.

Remarks
The holotype is somewhat damaged, which appears to have occurred at the time of collection. The abdomen is detached from the body, the right pedipalp and two right legs are missing, and the carapace is damaged which makes it extremely difficult to determine the number of eyes and carapaceal setation.

*Anapistula cuttacutta* is known only from a single male taken from a cave in the Katherine region of the Northern Territory.

Etymology
The specific epithet is a noun in apposition taken from the type locality.

*Anapistula jerai* sp. nov.
Figures 12-14

Material Examined

**Holotype**
δ, Gunong Jerai, Kedah State, Malaysia, 5°48'N, 100°26'E, 550 d, 12 September 1982, rainforest berlesate, R.W. Taylor, R.A. Barrett (ANIC).

**Other Material**


**Diagnosis**
Males of *A. jerai* differ from all other species by the lack of a lateral flange or distal bifurcations on the dorsal element of the conductor (C2) and by the lack of a basally expanded ventral element of the conductor (C1) (Figures 12). Females cannot be separated from those of *A. bifurcata* but differ from all other species by the following combination of characters: spermathecae spherical (Figure 14); median epigynal duct reaching to tip of spermathecae (Figure 14); and femur I 0.26 mm in length.

**Description**

**Male (Holotype)**
Total length 0.41. Carapace 0.20 long, 0.21 wide, 0.11 high. Femur I 0.29 long. Colour entirely pale yellow. Carapace with 8 setae, 4 on clypeus, 2 on eyes, and 2 on posterior ridge of pars cephalica; pars cephalica only slightly higher than pars thoracica; 4 distinct eyes, surrounded by dark pigment; PME completely absent. Chelicerae fused only subbasally; distal lobe of fang furrow with 2 conical teeth. Sternum posteriorly truncate. Pedipalp (Figures 12, 13): femur without tubercles on ventral face; tibia without retrolateral apophysis; cymbium broad and cup-shaped, with hooked basal paracymbium; embolus coiled twice, embolic duct looped; median apophysis distally

**Figures 12-14 Anapistula jerai** sp. nov., holotype δ: 12, left pedipalp, retrolateral; 13, left bulb, with conductor omitted, showing embolic duct; paratype female (from Kampong Segu, Sarawak, Malaysia): 14, epigyne, ventral.
broad; conductor comprising two discrete elements which enclose the embolus: ventral element (C1) basally narrow and gradually tapering to a distal pointed projection; dorsal element (C2) subdistally spatulate with broad circular depression. Legs: femur I without tubercles; all patellae with retrolateral protuberance containing patch of lyriform organs; all tarsal claws without teeth. Posterior spiracles present. Colulus absent.

**Female (ANIC, from Kampong Segu, Sarawak)**

Total length 0.48. Carapace 0.21 long, 0.17 wide, 0.09 high. Femur I 0.26 long. Colour entirely pale yellow, except for sclerotised internal genitalia and pigment surrounding eyes. Carapace with 8 setae, 4 on clypeus, 2 on eyes, and 2 on posterior ridge of pars cephalica; pars cephalica only slightly higher than pars thoracica; 4 distinct eyes, surrounded by dark pigment; PME completely absent. Chelicerae fused only subbasally; distal lobe of fang furrow with 2 conical teeth. Sternum posteriorly truncate. Pedipalp absent except for coxa. Legs: femur I without tubercles; all patellae with retrolateral protuberance containing patch of lyriform organs; all tarsal claws without teeth. Epigyne (Figure 14): spermathecae spherical, connected to single T-shaped copulatory duct; bases of copulatory duct with anterior swelling; heavily sclerotised triangular apophysis absent. Posterior spiracles present. Colulus absent.

**Remarks**

*Anapistula jerae* is known from four southeast Asian localities: Gunong Jera, northern Malaya; southwestern Sarawak; southern Kalimantan; and Anak Krakatau in the Sunda Strait. The latter is an island formed during the 1930's as a result of volcanic activity of the active volcano Krakatau (Thornton and Rosengren 1988). The association of these four specimens is slightly tenuous, but can be supported by the extremely small size of all specimens, and by their relative geographical proximity. More males are required from the region to confirm the association of the three females with the male from Kedah.

**Etymology**

The specific epithet is a noun in apposition taken from the type locality.

*Anapistula tonga* sp. nov.

*Figures 15–19*

**Material Examined**

*Holotype*

♂, Tongatapu, Tonga [ca. 21°10'S, 175°10'W], 12 March 1988, 88-014, [T.] Iliffe (AMNH).

![Figures 15–19](image-url) Anapistula tonga sp. nov., holotype ♂: 15, left pedipalp, retrolateral; 16, left pedipalp, prolateral; 17, left bulb, with conductor omitted, showing embolic duct; 18, right paracymbium, dorsal; paratype female; 19, epigyne, ventral.
Paratypes

**Tongatapu**: 3 ♂, same data as holotype (AMNH).

Diagnosis

Males differ by the shape of the ventral element of the conductor (Cl) which is basally very broad and abruptly tapering (Figure 15). Females differ by the following combination of characters: spermathecae spherical (Figure 19), median epigynal duct reaching to tip of spermathecae (Figure 19), and femur I 0.32 mm in length.

**Description**

**Male (Holotype)**

Total length 0.65. Carapace 0.25 long, 0.26 wide, 0.12 high. Femur I 0.32 long. Colour entirely pale yellow. Carapace apparently with 6 setae, 4 on clypeus and 2 on eyes; pars cephalica only slightly higher than pars thoracica; 4 small, distinct eyes, but not surrounded by dark pigment; PME completely absent. Chelicerae fused only subbasally; distal lobe of fang furrow with 2 conical teeth, mesal tooth slightly larger than lateral tooth. Sternum posteriorly truncate. Pedipalp (Figures 15–18): femur with small tubercles on antero-ventral face; tibia without retrolateral apophysis; cymbium broad and cup-shaped, with hooked basal paracymbium; embolus coiled twice, embolic duct looped; median apophysis small, conical; conductor comprising two discrete elements which enclose the embolus: ventral element (Cl) basally very broad and abruptly tapering to a distal pointed projection; dorsal element (C2) subdistally spatulate with broad circular depression. Legs: femur I without tubercles; all patellae with retrolateral protuberance containing patch of lyriform organs; all tarsal claws without teeth. Posterior spiracles present. Colulus absent.

**Female (Paratype)**

Total length 0.66. Carapace 0.24 long, 0.21 wide, 0.15 high. Femur I 0.32 long. Colour entirely pale yellow, except for sclerotised internal genitalia. Carapace apparently with 6 setae, 4 on clypeus and 2 on eyes; pars cephalica only slightly higher than pars thoracica; 4 small, distinct eyes, but not surrounded by dark pigment; PME completely absent. Chelicerae fused only subbasally; distal lobe of fang furrow with 2 conical teeth. Sternum posteriorly truncate. Pedipalp absent except for coxa. Legs: femur I without tubercles; all patellae with retrolateral protuberance containing patch of lyriform organs; all tarsal claws without teeth. Epigyne (Figure 19): spermathecae spherical, connected to single T-shaped copulatory duct; bases of copulatory duct with anterior swelling; heavily sclerotised triangular apophysis absent. Posterior spiracles present. Colulus absent.

**Remarks**

This large species is known only from Tongatapu situated in the Pacific Ocean.

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**Figures 20–21** *Anapistula boneti* Forster, holotype ♂: 20, right pedipalpal cymbium and bulb, prolateral; 21, abdomen, lateral.
Etymology
The specific epithet is a noun in apposition taken from the type locality.

ACKNOWLEDGEMENTS
I wish to thank Norman Platnick for placing much of the material listed above at my disposal and for alerting me to some recent literature, and to Bill Humphreys for access to his fascinating collection of cavernicolous invertebrates, which included material of two troglobitic species. Other material was graciously loaned by Christina Deelcman-Reinhold (Netherlands), Mike Gray (AM), Bruce Halliday (ANIC) and Robert Raven (QM). Field work in the Cape Range area was made possible with funds generously made available by W.H. and M. Butler. Norman Platnick kindly reviewed a draft of the manuscript.

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A new Jurassic theropod dinosaur from Western Australia

John A. Long and Ralph E. Molnar

Abstract - A Middle Jurassic (Bajocian) theropod dinosaur, Ozraptor subotaii, gen. et sp. nov., is described from the Colalura Sandstone of Western Australia, based on the distal end of a left tibia. The astragalar facet indicates that the dorsal process of the astragalus was high and distinctly rectangular in outline, with an anterior surface that is almost straight along its dorsal margin. It differs from all other theropods in which the tibia or astragalus is known as these have either weakly developed, low dorsal processes or high triangular-shaped processes. The specimen is significant in being the first Jurassic theropod bone from Australia, and the first Western Australian dinosaur to be formally named, apart from an ichnotaxon.

INTRODUCTION

Australian dinosaurs are known mostly from scant and rarely articulated remains of Early Cretaceous age in Victoria, New South Wales, South Australia and Queensland (Molnar 1991; Long 1993, 1998). The only Jurassic dinosaurs so far described are the partial skeleton of the sauropod Rhoetosaurus brownei (Longman 1927) from southern Queensland, and a report of a probable sauropod caudal vertebra by Long (1992) from near Geraldton, Western Australia. The bone described herein comes from the same site as the latter, the Bringo railway cutting about 20 km east of Geraldton, which exposes the Middle Jurassic Colalura Sandstone. The Colalura Sandstone is dated by its stratigraphic position. Immediately overlying it is the Bringo Shale (approximately 2 metres thick) and then the Newmarracarra Limestone which contains a diverse marine invertebrate fauna including abundant bivalves and ammonites. It has been referred to the Sowerbyi and perhaps Sauzei and Humphriesianium Zones of the European Middle Bajocian.

In addition to the two dinosaur bones, the Colalura Sandstone has abundant fossilised wood, bivalves, and rare reptilian bones including an isolated plesiosaur vertebra [WAM 86.10.707, figured by Long (1993, p. 53); UWA 36112; Long and Cruickshank 1998], and a possible paddle bone from a plesiosaur (WAM 63.5.13).

The western half of the Australian continent has been almost devoid of dinosaur skeletal remains until Long (1992) described a possible theropod humerus from the Late Cretaceous (Maastrichtian) Miria Formation of the Carnarvon Basin and the probable sauropod caudal vertebra from Bringo Cutting. Long (1995) also gave a brief description of a Late Cretaceous theropod pedal phalange from the Molecap Greensand near Gingin, and Long and Cruickshank (1996) described a possible Early Cretaceous theropod caudal vertebra from the Birdrong Sandstone, exposed near Kalbarri. However, an extensive assemblage of dinosaur footprint taxa are now known from the Early Cretaceous Broome Sandstone, including the theropod ichnotaxon Megalosaupros broomensis Colbert and Mereilles 1967, at least two different kinds of sauropods (Thulborn et al. 1994: 92), a variety of ornithopods including Wintonopus sp. (Long 1993, 1998), and a thyreophoran, possibly a stegosaur (Long 1993). This footprint assemblage is currently under study by Dr Tony Thulborn and Mr Tim Hamley, University of Queensland, Zoology Department, ably assisted by Mr Paul Foulkes of Broome. Figure 1 shows all known Mesozoic reptile sites in Western Australia, and their relative stratigraphic positions.

The specimen described here was found in 1966 by four year 12 Scotch College students, Steven Hincliffe, Peter Peebles, Robert Coldwell and Trevor Robinson (deceased), who visited the region to collect fossils. They gave the bone to Professor Rex Prider of the University of Western Australia who made casts and sent them to the British Museum of Natural History in London. At this stage the bone was still embedded in matrix. A note found with the specimen indicates that it had been shown to Dr A. Charig who thought it might be a turtle bone. In 1989, when one of us (JL) was appointed as curator of vertebrate palaeontology at the Western Australian Museum, a review of the Mesozoic vertebrates of that state was initiated. All material from the UWA collections was studied. The specimen was only recently prepared from the
rock by hammer and chisel, and consolidated with dilute Mowital B30 in acetone. Although this specimen represents the first skeletal material of a Jurassic Australian theropod, tracks are known from Queensland (Hill et al. 1966). Among these, at least one track from a small theropod, probably of Bajocian-Bathonian age, is comparable in size to this material (Hill et al. 1966).

SYSTEMATIC PALAEONTOLOGY

Although the specimen described here is based on a single incomplete bone, it is well known that in theropods the shape of the astragalus, or its corresponding facet on the tibia, can be distinctive at the generic level or above (Paul 1992; Welles and Long 1974; Molnar et al. 1981, 1996; Molnar and Pledge 1980). As this is also the first Australian Jurassic theropod recorded from skeletal material, it is unlikely to be confused with any described existing dinosaur skeletal remains. The closest theropod both in age and geographic proximity is Cryolophosaurus elliotti Hammer and Hickerson, 1994, from the earliest Jurassic of Antarctica, which apparently has the astragalus and calcaneum fused to the tibia (specimen examined by JL in 1996).

Order Saurischia Seeley 1888
Suborder Theropoda Marsh 1881
Family Incertae Sedis
Genus Ozraptor gen. nov.

Type Species
Ozraptor subotaii sp. nov.

Diagnosis
A small theropod dinosaur having the distal end of the tibia with a high rectangular, well-defined facet for the ascending process of the astragalus set into the anterior surface of the tibia. This facet has a relatively straight, dorsal margin, and a distinct vertical ridge centrally placed. Medial malleolus weakly developed.

Etymology
After "Oz" colloquial usage, short for Australia, and "raptor" meaning robber, a now popular
Figure 2  *Ozraptor subotaii* gen. et sp. nov., holotype UWA 82469. Distal end of left tibia in lateral view (A), anterior view (B), posterior view (C), and medial view (D). Bone whitened with ammonium chloride.
reference to small theropod dinosaurs (Currie 1997). One may therefore (metaphorically) think of Ozraptor as 'the lizard of Oz'.

Ozraptor subotaii sp. nov.

Material Examined
Holotype UWA 82469, distal end of left tibia (Figures 2, 3); only specimen.

Type locality
Found on the ground at the Bringo Railway Cutting, about 20 km east of Geraldton, Western Australia. Identified as being derived from the Colalura Sandstone (Bajocian) because the associated matrix shows the lithological characteristics of that unit, and included fossil wood.

Diagnosis
As for genus, only species.

Remarks
Molnar & Fledge (1980) erected the new theropod genus Kakurri based on the distal end of a right tibia, with a well-preserved astragalar facet. They argued, following the study of Welles and Long (1974), that the shape of the ascending process of the astragalus was unique. Here we iterate the same argument: in no other theropod is the astragalus developed as an almost rectangular dorsal process with a straight dorsal margin.

Welles and Long argued that the shape of the astragalar ascending process could be used to recognise major groups of theropods, and this character is still used in contemporary phylogenetic classifications (e.g., Gauthier 1986; Sereno 1997). If so, it is expected that the form in Kakurri is not actually unique but indicative of an otherwise unknown group of theropods. This is supported by the later publication (Taquet 1985) of a Moroccan Liassic theropod with a similarly formed ascending process. Although in the published figures the astragalus resembles those of ceratosaurs, examination of this specimen by REM reveals that this is misleading because the medial edge and apex of the ascending process are broken. Examination of the break on the astragalar body shows that the process did not extend across the body. Thus, like that of Kakurri, the ascending process of this unnamed taxon was high, but did not cover the entire anterior face of the tibia. This, in combination with the occurrence of these forms in regions where the dinosaurian fauna is poorly known, suggests that these 'aberrant' forms do not invalidate the use of the form of the astragalar process in recognising theropod taxa, but instead indicate that some Gondwanan theropod groups were not represented, or yet documented, in the northern continents.

The Bringo Cutting specimen is readily recognised as a distal tibia from the characteristic triangular distal form and ridge on the posterior surface behind the medial malleolus found in bipedal dinosaurian tibiae. The presence of a facet
New theropod dinosaur

Figure 4 Allosaurus fragilis, Late Jurassic, North America. Diagram showing left tibia in anterior view (A) and shape of astragalus and calcaneum fitted to front of tibia, showing close corroboration of astragalus shape to groove on tibia.

for the ascending process of the astragalus shows that the tibia represents a derived theropod (Rowe and Gauthier 1990).

Description
The bone is unfortunately much abraded along the lateral and distal margins, thus the latter is not well defined. The distal end of the left tibia, as preserved, measures 40 mm across at the broadest and the shaft is 19.6 mm thick at its thickest. The mid cross-section of the shaft is tear-shaped. The distal end of the bone is quite asymmetric due to the well-developed lateral flange behind the fibula, as is typical of theropod tibiae. The astragalar facet measures approximately 35 mm high from the distal end of the bone, and is 20.6 mm wide at its dorsal edge. The facet is depressed slightly into the shaft, unlike other derived theropods, where the ascending process may abut a step in the anterior face of the tibia (as in Megalosaurus) but does not rest ‘beneath’ the general level of the anterior face. The dorsal margin of the astragalar facet is well-developed as a strong shelf, gently curving out to meet the anterior face of the shaft, most strongly defined medially. The facet has a distinct median ridge extending vertically down its centre, weakly expanded distally. The dorsal margin is slightly offset at its junction with this ridge, with the lateral portion set more distally than the medial. The medial margin of the astragalar facet is straight. The extensor surface of the tibia is slightly concave at the fibular flange, becoming weakly convex dorsally along the shaft. The medial malleolus is abraded, yet from the overall shape of the bone it appears that it was not prominent, and may have been truncate as in Megalosaurus and Poekilopleuron (Molnar et al. 1996). The medial surface adjacent to the facet is extremely narrow, due to the great width of the astragalar facet.

The estimated length of the bone, by comparison with other similarly robust, although larger, theropod tibiae is approximately 17-20 cm, giving an estimated maximum body length in the range of about 1.6-2 m (by comparison with Sinraptor dougi [Currie and Zhao 1993] and Allosaurus fragilis [Madsen 1976]).

Etymology
After the fictional character Subotai, a swift running thief from the film “Conan the Barbarian” (1982, Universal Pictures), based on the Robert E. Howard books.

COMPARISON WITH OTHER THEROPODS
The range of theropods of the Late Triassic and Early-Middle Jurassic include slender, small forms with elongate tibiae, such as Syntarsus and Coelophysis, as well as larger, more robust forms,
such as Dilophosaurus. In these ceratosaurs, the astragalus is broad and low with a weakly to moderately developed triangular dorsal process (Rowe and Gauthier 1990, fig. 5.9; Welles and Long 1974), as also in the Late Jurassic Sinraptor (Currie and Zhao 1993). Or it is sometimes fused to the tibia and calcaneum as a tibiotarsus (e.g., Svtitarus, Coelophysis, Lilicresternus; Rowe and Gauthier 1990, fig. 5.9).

In Jurassic megalosauroids the astragalar ascending process has a similar form, but is moderately high (compared to Cretaceous taxa). In Megalosaurus andrewesi, Megalosaurus bucklandi, Poikilopleuron bucklandi and Eustreptospondylus oxoniensis the astragalar facet is probably triangular (Molnar and Pledge 1980; Welles and Long 1974). Among other Jurassic theropods, Piatnitzkysaurus, from South America, also has a low, triangular astragalus, as restored from the specimen (F. Manning, pers. comm., 1979). The set of tarsals and only one tibia are present in the megalosauroid specimen. In the facet indicates a high astragalar dorsal process, similar to those of a ceratosaur. Allosaurus fragilis, from the Late Jurassic of North America (Figure 4), shows a higher ascending process on the astragalus, but still retains the distinctly triangular shape, accurately reflected by the facet on the flexor surface of the tibia (Figure 3). Molnar et al. (1991) characterise the allosaurid astragalus by six main features which reflect the specialised mode of attachment of the ankle bones to the tibia. Other larger Jurassic taxa, such as Gaviosaurus, Kujjungasaurus, Kuparii and Marshosaurus apparently lack distal ends of their tibiae and tarsals.

But most relevant are the smaller theropods, Coelurus, Chauniodongocoelelus and Ornitholestes. As reconstructed the ascending process of Ornitholestes is low and moderately narrow. Unfortunately the basis of this reconstruction is unknown, as neither set of tarsals and only one tibia are present in the specimen (E. Manning, pers. comm., 1979). The astragalar facet is not now exposed on the mounted skeleton in Coelurus the facet indicates a broad, high ascending process, that is more commonly found in the Cretaceous. Only the base of the ascending process appears to be preserved in Chauniodongocoelelus, but it is such that it could match the form of the facet in Ozraptor (He 1984). However the distal profile of the tibia is substantially different.

Our survey of astragalar shapes and tibial morphology in Jurassic theropods fails to find any similar to that of Ozraptor. Furthermore, the conservative triangular form of the dorsal process of the theropod astragalus is accentuated in many of the Cretaceous forms, such as ornithomimosaurids, oviraptorosaurids (including elmisaurids), dromaeosaurids and troodontids (Barsbold and Osmolska 1990; Barsbold et al. 1990; Currie 1990; Ostrom 1990; Molnar and Pledge 1980; Molnar et al. 1996). It is extremely high in the juvenile troodontid Saurornithoides mongolensis (Currie and Peng 1993, figure 1-0). Welles and Long (1974) reviewed the shape of the tarsus in theropod dinosaurs, and this was reiterated and supplemented by Molnar et al. (1996). Neither papers mentioning a square astragalal facet (or similarly shaped astragalus) in any known genus. The only other dinosaur showing an astragalus with a relatively transverse dorsal margin is the troodontid Borogovia (Osmolska and Barsbold 1990), although in this form it has an extremely high dorsal process on the astragalus which is fused to the tibia, so is distinctly different from that of Ozraptor. Figure 5 shows these differences by comparing the common shapes of tibiae and astragali for various theropod groups.

We conclude, based on the relative size and almost square shape of the dorsal process of the astragalus in Ozraptor, that it has no intimate relationship with any theropods so far described.

DISCUSSION

The only East Gondwanan theropod of this age described from skeletal remains (rather than footprints) is the Early Jurassic Cryolophosaurus ellioti from Antarctica. This appears to have a fused tibia, astragalus and calcaneum, assuming the postcranial material is correctly associated with the holotype skull, as cautioned by Hammer and Hickerson (1994). The Cretaceous abelisaurids are another group of Gondwanan theropods known primarily from South America, but also recorded from Madagascar and India (Bonaparte 1991). Of these, only Xenotarsosaurus has a well-preserved tibia, indicating fusion of the astragalus and calcaneum to its distal extremity, as is thought to be the case for Cryolophosaurus.

Thus comparisons show that Ozraptor is unique amongst theropods in its inferred astragal shape and the depression of the astragal facet, and cannot be placed in any existing theropod family on this basis.

The functional morphology of the astragal shape may tell us something about the nature of the theropod lifestyle. Those theropods having high astragal dorsal processes are the more agile, often small to medium-sized forms (e.g., ornithomimosaurids, oviraptorosaurids, elmisaurids, dromaeosaurids, and some smaller tetanurans) as well as large predators like tyrannosaurids. In terms of the astragal shape and possible locomotory implications, Ozraptor is more derived.
Figure 5 Comparisons between theropod distal ends of tibiae, and/or astragalus shapes in approximate chronological order. The astragalus shape is restored for Ozraptor gen. nov. These are not drawn to scale. Abbreviations: Acro., Acrocanthosaurus; Allo., Allosaurus; asc.pr, ascending process of astragalus; Boro., Borogavus; Calam., Calamosaurus; Coel., Coelophysis; Dein., Deinonychus; Delt., Deltadromeus; Dil., Dilophosaurus; Kak., Kakurilus; Ing., Ingenia; Lil., Liliensternus; Meg.b, Megalosaurus bucklandi; Oz., Ozraptor gen. nov.; Pian., Pamatikpatsaurus; Poik., Poikilopleuron; Saur., Saurornithoides (juvenile); Segn., Segnosaurus; Sinr., Sinraptor; Spn., Spinosaurus; Syu., Syntarsus; Tyr., Tyrannosaurus; Yang.s, Yangchuanosaurus shangyuensis; Xen., Xenotarsosaurus.
than other contemporary Early-Middle Jurassic forms none of which have a high, broad ascending process on the astragalus. The central groove on the posterior face of the astragalus, suggested by the central ridge seen on the anterior face of the tibia is a feature seen also in *Allosaurus fragilis*, *Allosaurus* sp. (Molnar et al. 1981) and possibly *Sinraptor dongi* (from figures 23E and F in Currie and Zhao 1993), but has not been found from the few figured examples of ceratosaurians. In *Dilophosaurus*, for example, the posterior face of the astragalus seems to be smooth (Rowe and Gauthier 1990, figure 5.9K).

We speculate that the high, broad ascending process may be (partially) 'locked' in place by the central ridge, suggesting resistance to stresses at the ankle. Because the high, broad ascending process seems correlated with small, agile forms, we suggest that *Ozraptor* was also an agile animal.

**Summary**

The few characters preserved on the distal tibia of *Ozraptor subotai* gen. et sp. nov. indicate that it represents a new taxon of theropod dinosaur that was relatively derived for its age. Biogeographically *Ozraptor* represents the only known Jurassic theropod from Australia (apart from ichnotaxa, see Long 1998 for details); and the oldest theropod bone from the continent.

**ACKNOWLEDGEMENTS**

We wish to thank Dr Bill Hammer and Mr Bill Hickerson, Augustana College, Illinois, for allowing the senior author to examine the type material of *Cryolophosaurus ellioti*, Dr Philippe Taquet, Museum National d'Histoire Naturelle, for allowing the junior author to examine theropod material from Morocco, and the Geology Department, University of Western Australia, for the transfer of the specimen and other Bringo Cutting material to the collections of the Western Australian Museum. Ms Kris Brimmell is thanked for her fine photography of the specimens and for making replicas of the bone.

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New theropod dinosaur


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Reviews, observations and results of research into all branches of natural science and human studies will be considered for publication. However, emphasis is placed on studies pertaining to Western Australia. Longer papers will be considered for publication as a Supplement to the *Records of the Western Australian Museum*. Short communications should not normally exceed three typed pages and this category of paper is intended to accommodate observations, results or new records of significance, that otherwise might not get into the literature, or for which there is a particular urgency for publication. All material must be original and not have been published elsewhere.

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The International System of units should be used. Numbers should be spelled out from one to nine in descriptive text; figures used for 10 or more. For associated groups, figures should be used consistently, e.g. 5 to 10, not five to 10.

Spelling should follow the *Concise Oxford Dictionary*.

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Synonymies should be given in the short form (taxon, author, date, page) and the full reference cited at the end of the paper. All citations, including those associated with scientific names, must be included in the references.

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The original and two copies of manuscripts and figures should be submitted to the Editors, c/- Publications Department, Western Australian Museum, Francis Street, Perth, Western Australia 6000. They must be in double-spaced typescript on A4 sheets. All margins should be at least 30 mm wide. Tables plus heading and legends to illustrations should be typed on separate pages. The desired position for insertion of tables and illustrations in the text should be indicated in pencil. Tables should be numbered consecutively, have headings which make them understandable without reference to the text, and be referred to in the text.

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The senior author will receive fifty free offprints of the paper. Additional offprints can be ordered at page proof stage.
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Cover: A mysid crustacean, Haplostyleus tenuicaudus sp. nov. from Nickel Bay, Western Australia. Illustration by Jill Ruse.
Emoia (Reptilia: Scincidae) from the Banda Arc islands of eastern Indonesia: variation in morphology and description of a new species

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Abstract - Skinks of the genus Emoia are widespread through the islands of the Pacific with 72 species recognised in a recent review, eight of these occur on the islands of eastern Indonesia. Only three of these described species were collected during a survey of this region between 1987-1993. The morphology of head shields and body scale counts of the specimens collected were subjected to univariate and canonical variate analysis. Emoia reimschisseli and E. longicauda were collected on Wokam island in the Aru group and on Selaru island in the Tanimbar group. There was a marked difference in morphology of head shields and body scale counts of the single specimen of E. reimschisseli from Selaru when compared to populations of this species from both Aru and Kai Besar islands. The Emoia similis collected on eastern Flores are morphologically similar to those collected previously from Flores and Komodo islands, but showed some differences in body patterning. The previously uncollected population of Emoia from Sumba island is described as a new species. It is closely allied to E. similis from Flores and Komodo.

INTRODUCTION

The vertebrate fauna of the islands of eastern Indonesia have long held an interest for biologists because they straddle the divisions and biota between two of the world's great biogeographic realms, the Asian and the Australasian (Wallace 1860). The islands of south-eastern Indonesia are arranged into two chains of different geological origins, the Inner and Outer Banda Arcs. Along these island chains the fauna of the two biogeographic realms come into contact, high levels of endemism are apparent (Vane-Wright 1991; Kitchener and Suyanto 1996; How and Kitchener 1997) and morphological and genetic differentiation occurs among species (Kitchener et al. 1993). An important factor determining this variation and endemism appears to be the alternating linkages between islands that occurred because of changes in sea-levels during Pleistocene glaciations (Schmitt, Kitchener and How 1995; How, Schmitt and Suyanto 1996).

A survey of the vertebrates on the islands of eastern Indonesia from Bali eastwards through the Inner and Outer Banda Arcs to Ambon, Kai and Aru was undertaken between 1987 and 1993 by the Western Australian Museum and the Museum Zoologicum Bogoriense, Indonesia. The survey documented the amphibians, birds, mammals and reptiles of some 28 islands during the course of 12 major surveys extending over eight years with a view to evaluating the species diversity and systematics in the zone of transition between the Asian and Australasian biogeographic realms.

Studies of the reptile fauna in the region have shown that there is significant intraspecific morphological variation in both lizard and snake species along the two island chains that form the Banda Arcs. Musters (1983) described subspecific variation in the volant dragon, Draco; Aplin et al. (1993) revised the species in the skink genus Glaphyromorphus and How et al. (1996a, 1996b) documented morphological variation in four colubrid and one viperid snake.

Brown (1991) recognised 72 species in Emoia across the range of the genus from south-east Asia, through the Indo-Australian Archipelago to the islands of the Pacific, where species are widespread and abundant. Emoia is most speciose on New Guinea and the satellite islands to the north and east along the Pacific Plate boundary but is poorly represented in the islands west of New Guinea. Brown (1991) documented seven species (E. atrocostata (Lesson), E. caeruleocauda (de Vis), E. sp. [baudini group], E. kuekenthali (Boettger), E. longicauda (Macleay), E. reimschisseli (Tanner), E. sorex (Boettger)) from the Maluku islands and three species of Emoia (E. atrocostata, E. caeruleocauda, E. similis Dunn) from the Lesser Sunda islands.
In this paper we report on new collections of *Emoia* from the islands of the Banda Arcs and Aru in eastern Indonesia. Species are identified on the basis of traditional meristic and colour pattern features and on multivariate analyses of head shield and body meristic variables. However, we are aware from recent studies of *Emoia* (Bruna et al. 1996) that traditional morphological analysis alone can fail to detect cryptic species that differ significantly at the molecular level and it is possible that this reappraisal may still overlook some cryptic species.

**METHODS AND MATERIALS**

Seventy-one specimens of *Emoia* were collected during the joint Western Australian Museum-Museum Zoologicum Bogoriense survey of the Lesser Sunda and eastern Maluku islands (Figure 1). Twenty nine *Emoia* were collected from Karranguli on the island of Wokam in the Aru group [AR], 13 from Elat and Mun on the island of Kai Besar [KB], two from Adaut on Soloru Island [SL], the southernmost island in the Tanimbar group, two from Larantuka on the eastern end of Flores Island [FL] and 27 from Ngallu on eastern Sumba Island [SB]. All numbers referring to individual specimens are Western Australian Museum reptile (R) collection numbers; the holotype and the majority of specimens will be housed in the Museum Zoologicum Bogoriense, Indonesia.

The following 17 head shield measures were made on all *Emoia* examined: - the length [L] and breadth [W] of the Rostral [ROS], Frontonasal [FRNA], Frontal [FRO], Frontoparietals [FRPA], Interparietal [INPA] (not present in *E. similis*) and the maximum length of the nasal [NAD], four supraocular scales [SUOC] and the two loreal [LO] scales. Counts were made of the mid-body scales [MIDBODY], the dorsal scale row along the midline between the parietals to the tail base opposite the vent [DORSAL] and the subdigital lamellae [SUBDIG] under the fourth toe of the hindlimb.

The snout to vent length [SVL] was taken from every specimen and the sex determined by internal examination of the gonads and their state of development. Juveniles were excluded from further analysis.

All measurements were made by the same observer using electronic callipers and made to the nearest 0.01 mm.

The variables were then subjected to canonical variate analysis (CVA). The best variables for discrimination were selected on the basis of maximising the MANOVA F value (i.e. minimising Wilks' lambda) in a forward stepwise procedure.
The number of significant variables chosen to discriminate was limited to six initially in order to avoid overfitting. The statistical packages Statistix (1992) and SPSS (1993) were used for all analyses.

**SYSTEMATICS**

Specimens from the islands of eastern Indonesia were initially identified using the key and descriptions provided in Brown (1991). Specimens were assigned to one of three taxa; *E. longicauda* (Aru - a male and Selaru - a female) from the cyanogaster Group and *E. reimschisseli* (Aru - 18 females, 8 males; Kai Besar - 7 females, 6 males; Selaru - a female) and *E. similis* (Sumba - 17 females, 10 males; Flores - 2 females) from the cyanura Group. The key separation between the *cyamira* females, 10 males; Flores - 2 females) from the *cyamira* Group and the *c. similis* (Aru - a male and Selaru - a female) from the *cyamura* Group is in the size and shape of the anterior loreal. The interparietal is absent in *E. similis*.

*Emoia reimschisseli* (Tanner) Brown (1991) considered *E. caeruleocauda reimschisseli* on Moratai and Halmahera islands in the Malukus without evidence of intergradation and raised it to a full species. Specimens from Aru, Kai and Selaru are referred to *E. reimschisseli* on the basis of their head shield pattern and the number and structure of their subdigital lamellae counts.

There was significant sexual dimorphism in 16 of the 21 variables measured from the population of *E. reimschisseli* on Aru Island (Table 1). Female values were significantly smaller than those in males for the variables SVL were, ROSH, ROSW, FRNAL, FRNAW, FROL, FROW, FRPAL, FRPAW, INPAL, INPAW, NAD, SUOC1, SUOC3, LO1 and LO2. Sex dimorphism was apparent in only one of the 21 variables from *E. reimschisseli* on Kai Besar Island; with females having a shorter INPAL (Table 1).

A comparison between the populations on Aru and Kai Besar showed significant differences between males in 13 of the 21 variables measured (Table 1) but no significant differences in any variable between the two females' populations.

The female from Selaru does not fit within the variation shown for this species from the populations on Aru and Kai Besar (Table 1). It is generally larger (SVL 73 mm) has fewer subdigital lamellae (26 cf. 31–36) and is consistently larger for all headshield measures than either the females or males from Aru and Kai Besar. It most probably

---

**Table 1** Measures of the variables taken from populations of *E. reimschisseli* on the islands of Aru and Kai Besar. Data are expressed as means and standard deviations. Significant differences between males in the two populations are expressed as *p<0.05, **p<0.01, ***p<0.001. Females showed no significant differences between populations. The significance levels indicated for females indicate those characters that are sexually dimorphic in the Aru and Kai populations. The data from the single female from Selaru is presented along with the measurements of the *E. longicauda* specimens from Aru and Selaru.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>MALES</th>
<th>FEMALES</th>
<th>F</th>
<th>M</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEX</td>
<td>ISLAND</td>
<td>ARU (8)</td>
<td>KAI (6)</td>
<td>ARU (18)</td>
<td>KAI (7)</td>
</tr>
<tr>
<td></td>
<td>SVL</td>
<td>68.38±7.43</td>
<td>*56.83±7.68</td>
<td>*58.50±12.64</td>
<td>58.29±3.95</td>
</tr>
<tr>
<td></td>
<td>DORSAL</td>
<td>71.00±1.93</td>
<td>68.83±2.93</td>
<td>70.11±2.25</td>
<td>68.86±2.61</td>
</tr>
<tr>
<td></td>
<td>MIDBODY</td>
<td>36.63±2.26</td>
<td>34.67±0.32</td>
<td>36.39±0.03</td>
<td>35.71±1.60</td>
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<tr>
<td></td>
<td>SUBDIG</td>
<td>32.50±1.20</td>
<td>33.83±2.14</td>
<td>32.56±0.92</td>
<td>33.00±1.73</td>
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<tr>
<td></td>
<td>ROSH</td>
<td>1.70±0.19</td>
<td>*1.40±0.20</td>
<td>*1.33±0.29</td>
<td>1.29±0.12</td>
</tr>
<tr>
<td></td>
<td>ROSW</td>
<td>3.03±0.30</td>
<td>**2.46±0.34</td>
<td>**2.43±0.50</td>
<td>2.34±0.19</td>
</tr>
<tr>
<td></td>
<td>FRNAL</td>
<td>2.86±0.31</td>
<td>**2.24±0.33</td>
<td>**2.29±0.46</td>
<td>2.07±0.25</td>
</tr>
<tr>
<td></td>
<td>FRNAW</td>
<td>3.37±0.39</td>
<td>*3.00±0.31</td>
<td>*2.82±0.51</td>
<td>2.77±0.19</td>
</tr>
<tr>
<td></td>
<td>FROL</td>
<td>3.93±0.50</td>
<td>3.45±0.60</td>
<td>*3.18±0.63</td>
<td>3.25±0.33</td>
</tr>
<tr>
<td></td>
<td>FROW</td>
<td>3.04±0.37</td>
<td>*2.52±0.23</td>
<td>*2.59±0.47</td>
<td>2.50±0.21</td>
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<tr>
<td></td>
<td>FRPAL</td>
<td>3.85±0.27</td>
<td>***3.17±0.29</td>
<td>**3.35±0.49</td>
<td>3.23±0.18</td>
</tr>
<tr>
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<td>FRPAW</td>
<td>4.01±0.43</td>
<td>3.58±0.37</td>
<td>**3.42±0.54</td>
<td>3.44±0.26</td>
</tr>
<tr>
<td></td>
<td>INPAL</td>
<td>1.69±0.12</td>
<td>*1.41±0.18</td>
<td>*1.36±0.26</td>
<td>*1.22±0.07</td>
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<tr>
<td></td>
<td>INPAW</td>
<td>1.19±0.10</td>
<td>1.06±0.13</td>
<td>*1.05±0.15</td>
<td>0.98±0.10</td>
</tr>
<tr>
<td></td>
<td>NAD</td>
<td>2.36±0.17</td>
<td>*1.98±0.28</td>
<td>*1.93±0.38</td>
<td>1.90±0.21</td>
</tr>
<tr>
<td></td>
<td>SUOC1</td>
<td>1.78±0.20</td>
<td>1.56±0.35</td>
<td>*1.44±0.26</td>
<td>1.35±0.14</td>
</tr>
<tr>
<td></td>
<td>SUOC2</td>
<td>1.63±0.13</td>
<td>*1.44±0.19</td>
<td>1.59±0.36</td>
<td>1.41±0.15</td>
</tr>
<tr>
<td></td>
<td>SUOC3</td>
<td>1.47±0.10</td>
<td>*1.21±0.16</td>
<td>*1.22±0.20</td>
<td>1.18±0.13</td>
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<td></td>
<td>SUOC4</td>
<td>1.94±0.42</td>
<td>*1.50±0.25</td>
<td>1.66±0.31</td>
<td>1.45±0.20</td>
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<td></td>
<td>LO1</td>
<td>1.19±0.13</td>
<td>*0.97±0.12</td>
<td>*0.98±0.18</td>
<td>1.00±0.09</td>
</tr>
<tr>
<td></td>
<td>LO2</td>
<td>1.61±0.19</td>
<td>1.38±0.32</td>
<td>*1.36±0.29</td>
<td>1.33±0.14</td>
</tr>
</tbody>
</table>
represents a new taxon that is closely related to *E. reimschisselii* but its formal description is premature given that only a single specimen exists.

The canonical variate plot of the six most significant variables determined from Wilks’ Lambda (SUBDIG, SUOC4, LO2, MIDBODY, DORSAL, FROW) indicates that the Selaru specimen is separate on the first canonical variate axis (Figure 2) and that Aru and Kai specimens are slightly separated on the same axis. There is a correct assignment of 92.3% of the 13 Kai Besar specimens and 92.3% of the 26 Aru specimens.

The four variables with the highest standardised canonical discriminant function coefficients were SUBDIG (-0.72171), MIDBODY (0.63321), DORSAL (0.46328) and FROW (0.45547).

*Emoia longicauda* (Macleay)

Two specimens from Aru and Selaru islands (R109540, R12327) best fit the descriptions of *E. longicauda* (see Table 2) from the islands of eastern Indonesia (Brown 1991; Auffenberg 1980) and are referred to this species. *Emoia longicauda* has been recorded previously on both Aru and Kai islands by Sternfeld (1920), but this is the first record of the species from Selaru. Both specimens have markedly different headshield measures and subdigital lamellae counts (Table 1), with bladelike subdigital lamellae in contrast to the rounded lamellae of *E. reimschisselii*, and both specimens have lower dorsal and midbody scale counts than *E. reimschisselii* and have markedly larger measures for all variables except ROSH, ROSW, INPAL and INPAW.

Both *E. longicauda* in the *cyanogaster* Group and *E. ruficauda* in the *cyanura* Group have a high number of blade-like subdigital lamellae under the fourth toe but the Groups are distinguished on the
basis of the former having fused nasals. However, despite the cyanogaster Group diagnosis presented in Brown’s (1991) key, his species description for E. longicauda indicates that supranasals are present in the species. The specimens from Aru and Selaru have more meristic features in common with E. longicauda than E. rificauda while supranasals are present in both species.

Emoia similis Dunn

Auffenberg (1980) examined the holotype and 12 other specimens of E. similis from Komodo together with the type and other specimens of Leilopisma kardarsani from Komodo and Padar islands described by Darevsky (1964b), concluding that they were conspecific and, consequently, synonymised Leilopisma kardarsani with Emoia similis.

Two specimens collected at Larantuka on eastern Flores (R105079, R105080) are tentatively referred to E. similis. These two E. similis females agree in general meristics with previous descriptions of the species from both Flores and Komodo (Brown 1991, Auffenberg 1980). However, the colour pattern of the E. similis examined in this study differ from the descriptions of specimens from Komodo and Padar in that they lack a vertebral stripe.

Auffenberg (1980) described the pattern of the Komodo specimens as: “Color brownish-black, brown, or brownish-gray above, with 5 silvery-white longitudinal stripes (sometimes paravertebral and dorsolateral stripes are cream or yellow)”. This pattern differs from the description of the eastern Flores specimens, where there is no sign of the 5 silvery white longitudinal stripes but where two pronounced lateral stripes exist flanking a broad relatively unpatterned pale dorsum. The two Emoia from Larantuka have been assigned to Emoia similis despite these pattern differences. They may represent a discrete taxon, but more specimens are needed to confirm this.

The series of 18 specimens from Ngallu, East Sumba, are referred to a new taxon, closely related to E. similis.

Emoia kitcbehneri sp. nov.

Holotype
R101877, in Western Australian Museum, adult male, collected by R.A. How, D.J. Kitchener, N.K. Cooper, J. Dell and A. Suyanto at Ngallu, East Sumba, Indonesia (12°06’30"S and 120°46’30"E), on 8th June 1989. The type specimen is to be lodged at the Museum Zoologicum Bogoriense, Bogor, Indonesia.

Paratypes
R101830, R101859–860, R101867, R101869–875, R101878–893, R101907 data as for the holotype.

Diagnosis
A small member of the cyanogaster Group and caeruleocauda Subgroup (sensu Brown 1991). Most like E. similis in lacking interparietals but differing in its smaller size (23–39 mm cf. 37–72 mm), more subdigital lamellae (24–31 cf. 21–23), lack of a vertebral stripe, blue tail and by having limbs that meet when addpressed against the body.

Description
SVL males 30–37, n = 10 and females 23–39, n = 17 females. Head medium length with rounded snout. Lower eyelid with undivided transparent disc. Ear opening nearly round and much smaller
Table 3  Measures of the variables taken from populations of *E. similis* and *E. kitcheiieri* on the islands of Flores and Sumba. Data are expressed as means and standard deviations. Significant pairwise differences between *E. kitcheiieri* males and females and between the females in the different species are expressed as *p<0.05, ** p<0.01, *** p<0.001.

<table>
<thead>
<tr>
<th>SPECIES VARIABLE</th>
<th>Emoia kitcheiieri MALES (N=10)</th>
<th>EMOIA kITCHEIIERI FEMALES (N=17)</th>
<th>Emoia similis FEMALES (N=2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVL</td>
<td>33.50±2.46</td>
<td>*30.24±3.40</td>
<td>***39.00±0.00</td>
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<tr>
<td>DORSAL</td>
<td>55.50±1.84</td>
<td>55.53±2.21</td>
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<tr>
<td>MIDBODY</td>
<td>28.00±1.76</td>
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<td>26.00±1.41</td>
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<td>SUBDIG</td>
<td>27.20±2.20</td>
<td>**26.59±1.62</td>
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<td>ROSH</td>
<td>0.76±0.08</td>
<td>*0.64±0.10</td>
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<td>1.29±0.18</td>
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<td>*0.78±0.11</td>
<td>*0.91±0.17</td>
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<td>1.41±0.15</td>
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<td>FRP AL</td>
<td>2.47±0.20</td>
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<td>*2.40±0.46</td>
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<tr>
<td>NAD</td>
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</tr>
<tr>
<td>SUP04</td>
<td>1.01±0.14</td>
<td>***0.87±0.07</td>
<td>***1.04±0.24</td>
</tr>
<tr>
<td>LO1</td>
<td>0.42±0.09</td>
<td>0.37±0.07</td>
<td>*0.45±0.02</td>
</tr>
<tr>
<td>LO2</td>
<td>0.68±0.12</td>
<td>*0.58±0.09</td>
<td>*0.72±0.15</td>
</tr>
</tbody>
</table>

Comparisons

Female *E. kitcheiieri* on Sumba were significantly smaller than the two female *E. similis* we collected on Flores for all variables except MIDBODY, SUOC2 and SUOC3 (Table 3). The subdigital lamellae count of 24 – 31 lies outside the range of that recorded from the literature for *E. similis* (Table 4). The canonical variate plot for *Emoia similis* and *E. kitcheiieri*, using the five (FROL, SUBDIG, LGI, SUOC2, FRNAL) most significant variables determined from Wilks’ Lambda, is shown in Figure 3. The Flores and Sumba taxa are clearly separated on the single discriminant axis. Considerable sexual dimorphism occurs in *E. similis* but SVL is not a significant variable in the canonical variate analysis with the highest standardised canonical discriminant function coefficients occurring for FROL (-2.01929), SUOC2 (1.42468), LO1 (-1.14351) and SUBDIG (1.00743).

The colour pattern of *E. kitcheiieri* differs from *E. similis* by not having the three dorsal and two lateral pale stripes (Brown 1991) or the five silvery-white longitudinal stripes (Auffenberg 1980). In the eastern Flores specimens of *E. similis* the dorsolateral stripe is pale and broad (almost a scale wide) and the adjacent laterodorsal stripe is broken across supraciliaries forward to the prefrontals and finishing posteriorly on basal third of the tail. Lateral colour dark brown-black with occasional grey flecks. Ventral scales grey. Distal two thirds of the tail iridescent blue in life.
and barely discernible. In *E. kitcheneri* the dorsolateral stripe is narrow (much less than a scale wide) and sharply defined with the laterodorsal stripe blackish and well defined.

### Habitat and Range

Only known from the area around Ngallu on the eastern end of Sumba Island. All specimens of *E. kitcheneri* were obtained from local collectors such that precise habitat details were not available. However, local collectors were seen catching specimens of *Glaphyromorphus butlerorum* Aplin, How and Boeadi, *G. emigrans* (Lidthe de Jude) *Lamprolepis smaragdina* (Lesson), *Sphenomorphusflorense* (Weber) and *Emoia kitcheneri* from kebuns and forest adjacent to the village.

### Etymology

After Dr Darrell Kitchener, Curator of Mammals at the Western Australian Museum, without whose drive, enthusiasm and tolerance of bureaucracy the extensive survey of islands in eastern Indonesia would never have been attempted or completed.

### DISCUSSION

This study examines at least four species of the genus *Emoia* that occur on the islands of the Banda Arcs. *Emoia reimischisseli* occurs on Kai Besar and Selaru islands as well as on the Sahul Shelf island of Aru; *Emoia longicauda* occurs on Selaru and Aru islands, *Emoia similis* on Flores and Komodo (Auffenberg 1980) and *Emoia kitcheneri* on Sumba.

### Table 4

Body lengths and scale counts from the present study and the literature for *E. similis* and *E. kitcheneri* from the populations on Flores-Komodo-Rinca and Sumba.

<table>
<thead>
<tr>
<th>STUDY</th>
<th>SVL-M Range</th>
<th>SVL-F Range</th>
<th>DORSAL Range</th>
<th>DORSAL Mean (N)</th>
<th>MIDBODY Range</th>
<th>MIDBODY Mean (N)</th>
<th>SUBDIG</th>
<th>SUBDIG</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Emoia similis</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auffenberg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This-Flores</td>
<td>39–39(2)</td>
<td>58–59</td>
<td>58.5(2)</td>
<td>26–26</td>
<td>26.0(2)</td>
<td>22–23</td>
<td>22.5(2)</td>
<td></td>
</tr>
<tr>
<td><em>Emoia kitcheneri</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This-Sumba</td>
<td>30–37(10)</td>
<td>23–39(17)</td>
<td>51–60</td>
<td>55.5(27)</td>
<td>23–34</td>
<td>27.8(27)</td>
<td>24–31</td>
<td>26.8(27)</td>
</tr>
<tr>
<td>X=33.5</td>
<td>X=30.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Of the four species examined, three (E. reinschisselli, E. similis and E. kitcheneri) are placed in the cyanura Group and one (E. longicauda) is placed in the cyanogaster Group - sensu Brown (1991). The key differences between the cyanogaster Group and the cyanura Group are in the size of the two loreals - with the length being approximately equal in the former and the first loreal being much smaller than the second in the latter - and the nasal bones, which are fused in the former but separated in the latter.

Races of E. longicauda have been documented previously by Sternfeld (1920) from the islands of Aru and Kai while Welch et al. (1990) report on E. atrocostata from Indonesia (east from Borneo and Java), E. cyanogaster (Lesson) as occurring on Ambon and the Aru and Kai islands, E. cyanura (Lesson) on Timor, Ambon, Ceram and the Aru, Kai and Tanimbar islands, E. kuekenthalii on Ambon, E. sembalunica (Mertens) on Lombok and E. similis on Komodo, Padar and Rinca. Emoia sembalunica is considered a synonym of E. similis (Auffenberg 1980, Brown 1991).

Brown (1991) stated that E. reinschisseli differed sufficiently from E. caeruleocauda (both species being in the cyanura Group) in the Moluccas to be considered a distinct species and that there was no evidence of intergradation. The principal differences between the two species were in colour pattern and both midbody scale row counts (30.44±1.20 cf. 30.84±1.78) and subdigital lamellae under the fourth toe (35.14±1.70 cf. 41.89±4.53). It is apparent from the data presented in Brown (1991), however, that there is no significant differences in the midbody scale counts of the two species. The majority of specimens of E. reinschisseli examined by Brown (1991) were from the island of Moratai with just a single specimen from Halmahera, whereas E. caeruleocauda specimens were from throughout the southwestern Pacific and from Papua-New Guinea, Ceram, Ambon, Sulawesi, Borneo and the Philippines.

The present study indicates that there is marked separation on the first canonical variate axis of the specimen of E. reinschisseli from Selaru from those populations of the species from Aru and Kai Besar islands. The variables weighting most heavily on this axis were subdigital lamellae counts and mid-body scale counts. This suggests that the population of E. reinschisseli from Selaru island in the Tanimbar group may be a discrete taxon, however, no assessment of the variation in population is possible as only a single specimen was obtained.

Detailed examinations of the headshields of two wide ranging skink taxa in eastern Indonesia, Mabuua multifasciata (Kuhl) and Lamprolepis smaragdina (Lesson), using multivariate methods has indicated that there is little morphological separation of populations from throughout the Banda Arc islands. In Lamprolepis smaragdina, however, the slight separation in multidimensional space of the populations from Banda, Kai and Aru islands from the remaining islands to the west is strongly supported by a genetic evaluation using electrophoresis of 24 allozymes (Schmitt et al. 1999). This pattern of genetic differentiation of taxa from within species that are morphologically conservative has been clearly documented by Bruna et al. (1996) in their study of Emoia impar and E. cyanura in the Pacific islands. Of particular note in the Bruna et al. study of these two recently recognised cryptic species of Emoia, has been the determination that both these species are more closely related genetically to other currently recognised taxa than they are to each other. In an examination of the molecular and morphological variation of species of skink in the genus Lipinia, Austin (1995) also detected morphological conservatism in species that were genetically quite distinct. These findings indicate the value of a combined genetic and morphological approach to the delineation of species boundaries within this complex regional skink fauna.

It is highly probable that there remains numerous undescribed taxa of lizards in the islands of eastern Indonesia as indicated by the description of new taxa associated with every major survey or revision of taxa from the archipelago (Dunn 1927, Mertens 1930, Darevsky 1964a, 1964b, Auffenberg 1980, Musters 1983, Aplin et al. 1993). This raises the prospect of finding even higher levels of endemism amongst the lizards of the region than that already documented for snakes of around 20% in Nusa Tenggara, 30% in the southern Maluku and 33% in the northern Maluku (How and Kitchener 1997).

ACKNOWLEDGEMENTS

The former Director of the Western Australian Museum, John Bannister, the present Director of the Western Australian Museum of Natural Science, Paddy Berry, and the past and present Directors of the Pulitzer Biologi, Bogor, Dr Kardasan and Dr Soetikno are thanked for their continuous support of the survey of the vertebrate fauna of Bali, Nusa Tenggara and the Maluku Islands.

Darrell Kitchener ensured that the considerable bureaucratic and logistic difficulties associated with this survey were overcome and his skills are responsible for much of what has been accomplished. Colleagues in the field Ibnu Maryanto, Maharadatunkamsi, Norah Cooper, John Dell, Dennis King, Chris Watts, Augustine Suyanto, Ken Aplin, Boead, Sue Hisheh, Lin Schmitt and Kirsten Tullis provided valuable assistance. We would extend a special
acknowledgement to Darrell Kitchener and Ron Johnstone for their humour and fortitude in dealing with difficult biotic and abiotic environments over a dozen surveys and half a dozen years. Norah Cooper was of great assistance in running and interpreting the multivariate statistics and John Dell assisted with the figures. Liné Schmitt made a valuable contribution to an earlier version of the manuscript.

Funding support was from the W.H. and M. Butler Fund for specific reptile collecting, the Western Australian Museum, a National Geographic Society grant to D. J. Kitchener, P R. Baverstock, L. H. Schmitt and R. A. How and the Australian Nature Conservation Agency to D. J. Kitchener.

REFERENCES


Irileka, a new heteropodine genus (Araneae: Heteropodidae) from Western Australia

David B. Hirst
South Australian Museum, North Terrace, Adelaide, South Australia 5000, Australia

Abstract - A new genus of the Heteropodinae, *Irileka*, and a new species, *I. iridescens* are described from Western Australia. *Irileka* is similar to *Keilira* Hirst from south-eastern Australia but differs from the latter in leg spination, cheliceral dentition and in the male and female genitalia. *Irileka* is more similar to unnamed species from Queensland.

INTRODUCTION

In the first of a series of papers on Australian huntsman spiders, Hirst (1989) described the new genus *Keilira* from south eastern Australia, mentioning that similar species of a possibly related genus were to be found in north Queensland. The description of a further new genus, *Irileka* from Western Australia, in this paper is a step towards clarification of those Queensland species.

MATERIALS AND METHODS

All measurements are in millimetres, made with an eyepiece graticule. Eye diameters, interspaces and MOQ measurements are expressed as relative to the diameter of an AME. Drawings were done with the aid of a camera lucida on a Wild microscope. All abbreviations are standard for the Araneae. Material is deposited in the Western Australian Museum, Perth (WAM).

SYSTEMATICS

Genus *Irileka* gen. nov.

Type Species

*Irileka iridescens* sp. nov.

Diagnosis

Small heteropodine spider with five pairs of spines ventrally on anterior tibiae. Male with iridescence on anterior of body; embolus thick at base then tapering to long thin straight tip; conductor absent. Female with elongate fossa and widely separated spermathecal sacs.

Description

Carapace raised, convex in profile, highest near fovea, sloping gently to clypeus (Figure 1). Foveal groove weak or indistinct. Anterior eye row slightly recurved, eyes subequal. Posterior eye row slightly procured. Clypeus about half width of an AME. Cheliceral fang groove with three teeth on promargin, three teeth on retromargin (Figure 2). Labium about 2/3 times as long as broad. Sternum more or less longer than broad, slightly convex. Legs 2143. Anterior legs with five ventral pairs of spines on tibia with one pair apically (Figure 3). Metatarsi usually with 3 spines prolaterally, patellae lack spines. Female palp tarsal claw with four short teeth. Male embolus thick at base, tapering to a pointed tip. Palpal tibia relatively long with a small prodorsal distal extension and anteriorly directed retrolateral apophysis. Female epigynum weakly sclerotized anterior and lateral to fossa; copulatory openings lateral to fossa; spermathecal sacs widely spaced.

Etymology

The generic name *Irileka* is derived from a rearrangement of letters in the related genus, *Keilira*.

*Irileka iridescens* sp. nov.

Figures 1-10, Table 1

Material Examined

Holotype

♂, Bandicoot Bay, Barrow Island, Western Australia, Australia, 20°52′04″S, 115°20′01″E, wet pitfall traps, 4 November–3 December 1993, M.S. Harvey, J.M. Waldock (WAM 96/799).

Allotype

Australia: Western Australia, ♀, between Roy Hill [22°37′S,119°57′E] and Nullagine [21°53′S, 120°07′E], in flood debris after cyclone 'Dean', 2–3 November 1980, A.M. Douglas, R. Shardlow (WAM 88/1751).
Figures 1-10 *Irileka irudescens* gen. et sp. nov. 1-6, holotype male: 1 carapace profile; 2 labium, right maxilla and chelicera; 3 right leg II, prolateral; 4-6 left palp, 4 prolateral; 5 ventral; 6 retrolateral. 7-10, allotype female, 7-8 abdomen, 7 dorsal, 8 ventral; 9-10 epigynum, 9 ventral; 10 dorsal. Scale lines: Figures 1, 3, 7, 8 = 1 mm; figures 2, 4, 5, 6, 9, 10 = 0.5 mm.
Irileka, a new heteropodine genus

Diagnosis
Male with iridescence on anterior of carapace, base of chelicerae, maxillae and coxae I; palpal tibial apophysis sickle-shaped; embolus thick at base then tapering to thin straight tip; conductor absent. Female with elongate fossa and widely separated spermathecal sacs.

Description

Male

Colour in alcohol: Carapace yellow posteriorly, yellow-brown laterally, red-brown anteriorly, intense brown suffusion; setae brown; ocular area, base of chelicerae, maxillae and coxae I reflect iridescent hues. Chelicerae shiny dark red-brown; sparse long grey-brown setae. Sternum yellow, but darker adjacent coxa I. Coxae yellow, but coxa I brown except apically. Legs yellow to yellow-brown, tibiae and metatarsi with faint markings of suffusion. Abdomen dorsally cream with brown setae and spots of suffusion; venter similar.

Eyes: AME diameter 0.35. AME: ALE: PME: PLE = 1: 0.91: 0.66: 0.86. Interspaces: AME-AME 0.57; AME-ALE 0.66; PME-PME 1.49; PME-PLE 1.77; AME-PME 1.31; ALE-PLE 0.97. MOQ: Anterior width: posterior width: length = 2.57: 2.80: 2.91. Width of clypeus to AME 0.46.

Chelicerae: Promargin with 3 teeth, middle largest; retromargin with 3 teeth, middle and distal teeth subequal.

Labium: Length 0.71, width 1.05; flattened corrugiform surface (Figure 2), scattered short grey setae. Maxillae: Length 1.56, width 1.05; flattened corrugiform surface, sparse long grey setae. Sternum: Length 1.99, width 2.06; slightly convex; long, numerous grey setae.

Legs: (Table 1). Scopula dense on tarsi and apically on metatarsi. Spines: Leg I, fe d2 p2 r3, ti r2 v10, mt p3 r2 v4; Leg II, fe d2 p3 r1, ti p2 r1 v10, mt p3 r2 v4; Leg III, fe d2 p3 r1, ti p2 r1 v6, mt p3 r2 v4; Leg IV, fe d2 p1, ti p2 v6, mt p4 r3 v4; Palp, fe d2 p1 all distal, ti d1 p3. Patellae lack spines. Claws: Teeth short; 6 on proclaw, 5 on retroclaw.

Abdomen: Integument lifted, 'V' shaped pattern of spots barely visible. Setae of short to moderate length.

Palps: Embolus straight, thick at base tapering to pointed tip along prolateral side of tegulum (Figures 4, 6). Tibial apophysis sickle-shaped (Figure 5).

Female

As in holotype but for the following:
Carapace length 4.31, width 3.69. Abdomen length 5.59, width 4.25.

Colour in alcohol: Carapace yellow-orange, brown suffusion, dark brown suffusion in ocular area. Chelicerae red-brown, distal half with brown suffusion. Maxillae and labium orange-brown. Sternum yellow. Legs yellow-orange, some circular marks of suffusion on tibiae and metatarsi dorsally. Abdomen damaged; cream with spots of brown suffusion, median spots form 'V' pattern (Figure 7), scattered spots ventrally (Figure 8).

Eyes: AME diameter 0.32. AME: ALE: PME: PLE = 1: 0.97: 0.72: 0.88. Interspaces: AME-AME 0.38; AME-ALE 0.44; PME-PME 1.22; PME-PLE 1.50; AME-PME 1.19; ALE-PLE 0.66. MOQ: Anterior width: posterior width: length = 2.38: 2.66: 2.94. Width of clypeus to AME 0.53.

Labium: Length 0.56, width 0.93. Maxillae: Length 1.28, width 0.80; convex, smooth. Sternum: Length 1.94, width 1.87. Legs: (Table 1). Spines: Leg I, fe p3, ti r2; Leg II, fe r3, ti r2; Leg III, fe r2; Leg IV, fe p2, ti r2 mt r3.

Genitalia: Epigynum small, weakly sclerotized anteriorly and laterally to narrow fossa (Figure 9). Copulatory openings lateral to fossa. Spermathecae widely separated (Figure 10).

Distribution
Known only from Barrow Island and the Pilbara in northern Western Australia.

Remarks
Although the types are from disjunct localities, comparable characters of the male and female appear to be in agreement and in the lack of other material and evidence to the contrary they are considered to be conspecific. Irileka differs from

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Leg measurements (in mm) of Irileka iridescens gen. et sp. nov. values are for holotype male with allotype female in parentheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg 1</td>
<td>2.06 (1.94)</td>
</tr>
<tr>
<td>Leg 2</td>
<td>3.49 (3.21)</td>
</tr>
<tr>
<td>Leg 3</td>
<td>3.31 (3.04)</td>
</tr>
<tr>
<td>Leg 4</td>
<td>1.10 (1.02)</td>
</tr>
<tr>
<td>Total</td>
<td>13.69 (12.97)</td>
</tr>
</tbody>
</table>
Keilira in the larger size, in the PE being relatively smaller, in lacking denticles between the retromarginal and promarginal cheliceral teeth, in the narrower labium, in having 5 ventral spine pairs on anterior tibiae, 3 spines on metatarsi I–III prolaterally, in the long palp tibia and in the male palpal tibial apophysis, in having a long tapered embolic tip, in lacking an embolic guide or conductor and in the curved ejaculatory duct, while the female differs in having an elongate fossa, widely spaced spermathecae and copulatory openings situated lateral to fossa.

A further unnamed genus (or genera) of the Heteropodinae occurs in Queensland, but is not congeneric with Keilira (Hirst 1989). The unnamed species appear to be more closely related to Irileka in sharing five or six ventral spine pairs on anterior tibia with the distal pair, lacking in Keilira, being present. Males lack a conductor, but a pale membranous area is present apically on the tegulum and is possibly a vestigial conductor. Carapace shape differs in being lower and flattish above, 3.5 times longer than high whereas in Irileka and Keilira the carapace is convex and 2.5 times longer than high. Median denticles are present on the chelicerae, prolateral metatarsi have two relatively long spines and patellae are often with spines. Further differences in male and female genitalia exclude inclusion in either Irileka or Keilira.

**Etymology**

The specific name refers to the iridescent colours seen on the male under light.

**ACKNOWLEDGEMENTS**

Thanks go to Dr M.S. Harvey and Ms J. Waldock (WAM) for the loan of material.

**REFERENCE**


Manuscript received 3 July 1997; accepted 29 April 1998.
First record of campodeids (Diplura: Campodeidae) from caves in Australia

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Abstract – Nine specimens of Campodeidae, collected from six caves in northern and northwestern Australia, all belonging to the same species, Cocytocampa humphreysi sp. nov., are described. The caves, located at Cape Range and Kimberley, Western Australia, and Katherine, Northern Territory, are separated by more than 2000 kilometres across an extremely arid region. The samples included at least two populations, separated on the basis of the number of microchaetae on urosternites II to VII, but the low number of specimens does not allow an accurate statistical treatment.

INTRODUCTION

Two species of cave-adapted Campodeidae are known from the Australian region: Leletocampa marthaleri Condé, 1982 from New Ireland (Lamerigamas Cave, Lelet Plateau, 1260 m) and Lepidocampa (s. str.) chapmani Condé, 1989 from Papua New Guinea (Okeermal Tem Cave, Finin Tel Plateau, Western Province, rain forest, 2300–2400 m). Leletocampa marthaleri exhibits several characters in common with other troglobiontic species (numerous sensilla – 10 here – in the cupuliform organ of the apical article of the antenna; elongate legs; claws unequale with laterotergal crests); in Lepidocampa chapmani only the cupuliform organ with 13 to 17 sensilla and length of cerci (unknown in Leletocampa) are diagnostic of a true cavernicolous species. In addition endogean representatives of the Lepidocampa weberi Oudemans complex are known from caves in Papua New Guinea, New Britain and New Ireland (Condé 1982, 1989).

Campodea (Indocampa) novaecaledoniae Condé, 1980 was described from a cave in New Caledonia (grotte de Ouauou, types), but specimens from two other caves (grottes d’Adio and de Koumac) and several endogean locations were provisionally referred to that species.

The new species here described has the appearance of an endogean species, with cupuliform organ housing but four sensilla; nevertheless it may be a cave-dwelling species “in status nascendi”, similar to some European species which have never been found outside a cave although they have none of the morphological criteria usually associated with the hypogean biotopes.

Seven specimens of the new species, referred to the genus Cocytocampa, were obtained from the Western Australian Museum (WAM), Perth, through the courtesy of Dr W.F. Humphreys, Senior Curator, Department of Terrestrial Invertebrate Zoology. These specimens comprise the total collection of campodeids made over several years from numerous visits to Cape Range and two months field work in the Kimberley and a single collection in the Northern Territory. Two further specimens from a cave in the Northern Territory were sent by the Museums and Art Galleries of the Northern Territory, Darwin, through the courtesy of Dr G.R. Brown, Curator of Entomology. Specimens were mounted in Marc André II medium and deposited in the following institutions: Western Australian Museum (WAM-BES numbers are field codes) and the Northern Territory Museum of Arts and Sciences (KAB). Morphological methods and terminology follow Condé (1956, 1982).

SYSTEMATICS

Order Diplura Börner, 1904

Family Campodeidae Westwood, 1874

Cocytocampa Paclt, 1957

Cocytocampa humphreysi sp. nov.

Material Examined

Holotype

Figures 1–4 Cocytocampa humphreysi sp. nov., holotype BES 4113. 1, Head, anterior part with frontal process (f) and the macrochaetae along the line of insertion of the antenna (a, i, p); 2, Sensillum of the third antennal article (left) and the same in Cocytocampa catalae, holotype female (right); 3, Sensillum of the maxillary palp; 4, Sensillum of the labial palp with the two accessory short setae. Figure 1. Scales: figure 1 = 100 μm, figures 2–4 = 25 μm.
First campodeids from caves in Australia

Table 1 Measurements of specimens of *Cocytocampa humphreysi* sp. nov.

<table>
<thead>
<tr>
<th>Characters (lengths in mm)</th>
<th>Holotype BES 4113</th>
<th>Paratype BES 4210</th>
<th>Paratype BES 680</th>
<th>Kimberley and Northern Territory populations (subspecies)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BES</td>
<td>BES</td>
<td>BES</td>
<td>BES</td>
</tr>
<tr>
<td>Body length</td>
<td>3.88</td>
<td>2.76</td>
<td>2.20</td>
<td>3</td>
</tr>
<tr>
<td>Leg I length*</td>
<td>0.64</td>
<td>0.47</td>
<td>0.40</td>
<td>0.39</td>
</tr>
<tr>
<td>Leg II length*</td>
<td>0.89</td>
<td>0.63</td>
<td>0.51</td>
<td>0.50</td>
</tr>
<tr>
<td>Microch. II-VII</td>
<td>57</td>
<td>45</td>
<td>50</td>
<td>21</td>
</tr>
<tr>
<td>Antennal art.</td>
<td>30</td>
<td>22/22</td>
<td>-</td>
<td>25</td>
</tr>
<tr>
<td>Cercus length</td>
<td>-</td>
<td>1.48</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Femur+tibia+tarsus

Paratypes


Table 2 Frequency distribution of the number of antennal articles recorded in *Cocytocampa* species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>20</th>
<th>22</th>
<th>25</th>
<th>27</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. perkinsi</em> (type species)</td>
<td>Hawai'i</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>C. solomonis</em></td>
<td>Solomon Is.</td>
<td>8</td>
<td>241</td>
<td>179</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>C. solomonis</em></td>
<td>New Ireland</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>C. s. borneensis</em></td>
<td>Borneo</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td><em>C. catalae</em></td>
<td>New Caledonia</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
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<tr>
<td><em>C. humphreysi</em></td>
<td>NW Australia</td>
<td>-</td>
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<td>-</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>-</td>
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</tbody>
</table>

Table 3 Averages and ranges (in brackets) for measurement ratios in *Cocytocampa humphreysi* sp. nov. from Cape Range. Ratio definitions follow Denis (1932). Holotype in bold. Macrochaetae are: ma = anteromedial, la = anterolateral, Ip = posteromedial; Ip/M is the ratio of length of Ip to the mean length of the marginal setae.

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Value</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Th. I</td>
<td>1.29</td>
<td>(1.13-1.24-1.50)</td>
</tr>
<tr>
<td>Th. II</td>
<td>0.85 (0.81-0.89)</td>
<td>1.71 (1.57-1.69-1.88)</td>
</tr>
<tr>
<td>Th. III</td>
<td>1.76 (1.63-1.70-1.96)</td>
<td>2.01 (1.96-2.07)</td>
</tr>
</tbody>
</table>

Diagnosis

Notal macrochaetae of thorax long and slender, shared with *C. catalae* Condé, 1980; antennae with 22-30 articles (16-20 in congeneric species), apical article with 4 sensilla in the cupuliform organ. Basicolliform sensillum of third article slender, finger-like; between d and e (sternal position); the sensilla of maxillary and labial palps slightly claviform, all about 10 μm long. Labial palp with 10-12 short setae along the anterior border and more than 80 neuro-glandular (gustative) setae on the posterior surface.

Frontal process (= rostrum) with three macrochaetae, the anterior 1.46 times length of posterior pair, the apex of anterior macrochaeta more barbed. 3+3 macrochaetae, i. p., relative lengths respectively 20, 23, 24, along the line of insertion of the antennae: a with two subapical barbs.

Other Material Examined


Description (Figures 1-4 and 8-12)

Tegument: Epicuticula without ornaments. Clothing setae slender and smooth.

Head: Antennae (Table 2) with 22-30 articles (16-20 in congeneric species), apical article with 4 sensilla in the cupuliform organ. Basicolliform sensillum of third article slender, finger-like; between d and e (sternal position); the sensilla of maxillary and labial palps slightly claviform, all about 10 μm long. Labial palp with 10-12 short setae along the anterior border and more than 80 neuro-glandular (gustative) setae on the posterior surface.
Figures 5-7  *Cocytocampa catalae* Condé, holotype female. Posterolateral macrochaetae of thoracic tergites I, II, III. Figures 8-10. *Cocytocampa humphreyisi* sp. nov., paratype female BES 4210; 8, Posterolateral macrochaeta of the thoracic tergite II; 9, Telotarsus and claw of right leg II, anterior view. Holotype female BES 4113; 10, Posteromedial part of urosternite V with microchaetae (mi) and Posteromedial macrochaetae (mp). Figures 5-8 and 10 scale = $E_{ch}$, 9 = $F_{ch}$. 
First campodeids from caves in Australia

Figures 11-12 Cyctocampa hunhreyesi sp. nov., holotype female BES 4113; 11, Urosternites II–VII, diagrammatic: mi = microchaetae; mp = macrochaetae posteriomedial; 12, Genital papilla: lateral genital valves with three short and five longer setae.
Thorax: Macrochaetae long, slender, with numerous short barbs which are distinct on the distal half. Relative lengths for the Cape Range specimens are shown in Table 3.

Tibia with one barbed ventral macrochaeta; tibial spurs with several rows of barbs. Claws subequal, angular, latero-tergal crests very reduced, transverse scratches near the base; telotarsal process setiform, slender, a little shorter than claws or subequal.

Abdomen: Urotergites I to VII without macrochaetae, 2+2 lp on VIII and 4+4 on IX, similar to the thoracic lp but a little shorter (x 0.92-0.95). Supra-anal valvule with one smooth subapical seta.

Macrochaetae. 2+2 on VIII and 4+4 on IX, similar to the thoracic but a little shorter (x 0.92-0.95). Lateral appendages of the holotype missing. Lateral appendages of the holotype viewed laterally: appendages cylindrical; four rows (WAM 1998/0157 [BES 3217], non-paratype) of glandular setae, 3+3 along the posterior margin, two rows of short and slender ordinary setae in front of the glandular ones.

Urotergites II-VII with 5+5 macrochaetae (mp missing). Lateral appendages of the holotype (female) subcylindrical (L/I = 1.77) with about 20 glandular setae 38. On the only male available (WAM 1998/0157 [BES 3217], non-paratype) viewed laterally: appendages cylindrical; four rows of glandular setae 31 along the posterior margin, two rows of short and slender ordinary setae in front of the glandular ones.

The macrochaetae of the cerci are a little shorter in the Cape Range specimens than in those from the Northern Territory (x 0.80-0.91), and the barbed section is a little shorter than the smooth one in Cape Range (x 0.86-0.93) and the reverse in Northern Territory (x 1.24-1.70). The bars are short and thin.

Etymology
The new species is named in honour of Dr W.F. Humphreys, Senior Curator, Department of Terrestrial Invertebrate Zoology, Western Australian Museum, who collected or gathered the material, sent it for study and provided information about the biotopes and the biogeography of the local fauna.

**DISCUSSION**

Microcampa, a monotypic subgenus of Plusiocampa, was established by Silvestri (1934: 519) for the small (1.80 mm TL) endogean species he described from Hawai‘i (Oahu), *Plusiocampa (Microcampa) perkinsi*. Ascertaining that Microcampa Silvestri, 1934 is preoccupied by *Microcampa* Kawada, 1930 (Lepidoptera), Paclt (1957: 27) introduced Cocytocampa nom. nov. as a subgenus of Litocampa Silvestri 1933: 117 which was erected at the same time to generic rank. According to Paclt, the subgenus Cocytocampa includes eight species from France (2), France and Switzerland (2), Mexico (1), Brazil (1), French Guinea (1) and Hawai‘i (1).

At the revision of the cotype of *perkinsi*,

| BES 4113 | holotype | Cape Range | 3.88 | 5+6 | 3+3 | 6+5 | 6+5 | 3+6 | 4+5 | 57 |
| BES 4210 | paratype | Cape Range | 2.76 | 2+2 | 3+4 | 4+4 | 5+5 | 4+4 | 4+4 | 45 |
| BES 680 | paratype | Cape Range | 2.20 | 6+5 | 4+5 | 5+3 | 5+5 | 4+5 | 3+2 | 52 |
| BES 2707 | | Kimberley | 3.10 | 3+2 | 2+2 | 2+2 | 2+2 | 3+2 | 0 | 21 |
| BES 3217 | | Northern Territory | 2.60 | 2+2 | 2+2 | 2+2 | 2+2 | 2+2 | 1+1 | 1+1 | 16 |
| BES 3217 | | Northern Territory | 1.26 | 1+1 | 1+1 | 1+1 | 1+1 | 1+1 | 1+1 | 12 |
| KAB 92-14 | | Northern Territory | 2.31 | 2+2 | 2+2 | 2+2 | 2+2 | 2+2 | 1+1 | 1+1 | 21 |
| KAB 92-14 | | Northern Territory | 2.51 | 2+1 | 2+2 | 2+1 | 1+1 | 1+1 | 1+1 | 16 |
preserved in the Bernice P. Bishop Museum, Honolulu (ctype 3747) — prescribed by the description of a new species from the Solomon Islands — Bareth and Condé (1972: 238) accepted Paclí's changes: *Litocampa (Cocylocampa) solomonis*; they emphasised however (loc. cit.: 237) the ambiguous diagnosis of *Litocampa* and the heterogeneity of the eight species included in the subgenus *Cocylocampa*, and stressed the similarity of *perkinsi* and *solomonis* with *Indocampa* Silvestri, 1933 a subgenus of *Campona* from the Indian, Madagascan and Australian regions. When *Cocylocampa solomonis* was recorded from New Ireland, Condé (1982: 720–741) separated *Cocylocampa* from *Litocampa*.

*Cocylocampa humphreysi* is distinct from *C. catalae* Condé, 1980 (subgen. *Litocampa*), an endemic species from New Caledonia (Mont Mou, 25–30 km NNW of Nouméa, 1220 m beneath stone), by the lp macrochaetae of the thoracic tergites with numerous short barbs (vs 2–3 long ones), the shape of the sensillum on the third antennal article (digitiform vs claviform) and the microchaetae on the urosternites II–VII (vs missing). These small setae were discovered in *C. solomonis* where they take up the medial region in two groups: the anterior group being less numerous than the posterior group which is located between the *mp*. The number of microchaetae increases during post embryonic growth and are variable between islands in the Solomons, being more numerous in females than in males (62–51 vs 43–26). The two females from New Ireland have 67 and 72 microchaetae. Microchaetae are absent from the other species of *Cocylocampa* but present in *Campona (Indocampa) intermedia* Condé, 1990 from Sabah, which has 26 setae (1+1 to 3+2 on each sternite) in the juvenile female and 12 in the larva (1+1 to 2+2 on one sternite). Similar microchaetae, but less numerous and external to *mp*, were recorded for *Campona (Indocampa) sutteri* Condé, 1953, from Sumba and C. (1) *delavrengi* Condé, 1982, from Papua New Guinea; in the latter species, the total number of setae is 21 for the female and 12 for the larvae. Lastly, they were also noted in the monotypic genus *Papricampa* Condé, 1982, from Papua New Guinea, the holotype male having 19 (1/3 to 2/3 on the middle of one sternite).

According to W.F. Humphreys (*in litt.* 30.10.95) "it is somewhat surprising that the species seems to be widespread given the differences in other groups" and, recently (7 July 1997) "... it is unlikely that endogeneous species will be found in the area. This is the case with many groups which, while not overtly troglomorphic, seem to have survived in the area because of the karst habitat".

It is possible that isolation is reflected in the number of microchaetae (45–57 vs 16–22) and the articles of the antennae (27–30 vs 22–25) but the number of specimens available does not allow any statistical treatment.

The five known species of *Cocylocampa* are restricted to the central and western Pacific Hawai'i (*perkinsi*), Solomon Islands and New Ireland (*solomonis*), New Caledonia and Australia (*catalae*, *humphreysi*), Borneo (*borneensis* in Condé 1990) and Thailand (*enticroides* in Condé 1994). The discovery of *Cocylocampa* brings to five the number of genera recorded from Australia, after *Campona*, *Campodella*, *Metriocampa* and *Notocampa* (Houston 1994).

The Campodeidae from Australia are in need of global revision, using type material, if available and in good condition, or at least topotypes. Most of the descriptions are old with few illustrations and many important characters are unknown. A lot of work is necessary before a satisfactory knowledge of the Australian Campodeidae can be achieved.

ACKNOWLEDGEMENTS

I wish to thank W.F. Humphreys, Western Australian Museum, Perth and G.R. Brown, Museums and Art Galleries of the Northern Territory, Darwin, for sending me rare and very valuable material from caves in Cape Range, the Kimberley and the Northern Territory. The comments about biotopes and fauna by W.F. Humphreys were very welcome. Finally, I am indebted to Lynn Ferguson, Longwood College, Virginia, for a preliminary revision of my English translation.

REFERENCES


*Manuscript received 29 August 1997; accepted 12 May 1998.*
Gastrosaccini mysids from Australia, with a description of a new species of *Haplostylus* and a key to species of the genus (Crustacea: Mysidacea)

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Abstract - Seven species of gastrosaccini mysids, one species of *Gastrosaccus* and six species of *Haplostylus*, are reported from the coastal waters of Australia, based on specimens deposited in the Western Australian Museum, Perth. Among them, one *Haplostylus* species from Western Australia is considered new and described as *H. tenuicaudus* sp. nov. The new species resembles the Australian congeners, *H. queenslandensis* (Bacescu and Udrescu, 1982), *H. udrescui* Greenwood *et al.*, 1991, *H. australiensis* Wooldridge *et al.*, 1992, and *H. dispar* Panampunnayil, 1997, but differs from all the related species by having the following characters: the telson is relatively more slender, length 3 times basal width, laterally armed with more than 10 spines, including the terminal spine, with the subterminal spine smaller than and placed close to the terminal spine; the exopod of the male third pleopod has the terminal segment consistently longer than the penultimate segment. A key to all known *Haplostylus* species is presented.

INTRODUCTION
Species of the genera *Gastrosaccus* and *Haplostylus* are common in tropical and subtropical coastal waters of the Atlantic and Indo-West Pacific regions. A total of 16 species, representing two species of *Gastrosaccus* and 14 of *Haplostylus*, have been reported from Australian waters, mainly based on specimens collected from the eastern coast (W.M. Tattersall 1940; Bacescu 1979; Bacescu and Udrescu 1982; Wooldridge and McLachlan 1986; Panampunnayil 1989, 1997; Fenton 1990; Greenwood *et al.*, 1991; Wooldridge *et al.*, 1992). Recent study by Panampunnayil (1997) disclosed the presence of five new species of *Haplostylus* from south-west Australia, but our knowledge of the group in the coastal waters of Western Australia is relatively scarce.

Recent studies of gastrosaccini mysids housed in the Western Australian Museum revealed seven species, representing one species of *Gastrosaccus* and six of *Haplostylus*. Among them, a species of *Haplostylus* from the shallow coastal waters of Western Australia is considered new, and reported here as *H. tenuicaudus* sp. nov. In this paper, all seven species are taxonomically discussed and a key to the genus *Haplostylus*, as yet still preliminary, is provided, based mainly on published data.

The total length is given in millimetres, measuring from the tip of the rostrum to the base of the terminal spine of the telson. All specimens examined in this study are deposited in the Western Australian Museum, Perth (WAM).

SYSTEMATICS

Subfamily GASTROSACCINAE

Genus *Gastrosaccus* Norman, 1868

*Gastrosaccus sorrentoensis* Wooldridge and McLachlan, 1986

**Figure 1**


Material Examined
Australia: Western Australia: 1 ♀ (9.8 mm), Warnbro Sound, south of Perth, date unknown (WAM 403-95).

Diagnosis
Rostrum moderately developed, subtriangular, shorter than broad (Figure 1a). Posterior margin of carapace fringed with spine-like filaments on almost entire margin and overlapping slit dorsolaterally (Figure 1b). Fifth abdominal somite with articulated posteromedial process (Figure 1c). Sixth abdominal somite with sharp transverse carinate swelling at anterior dorsal end. Telson armed laterally with 9 pairs of stout spines including terminal spine (Figure 1d). Endopod of uropod as long as, or slightly longer than exopod. Second segment of antennular peduncle armed with 2 stout spines (Figure 1a).

Distribution
Previously known only by the type specimens.
from Sorrento Beach near Perth, Western Australia (Wooldridge and McLachlan 1986). This is the second record of occurrence for the species.

Remarks
The Australian fauna is known to include two *Gastrosaccus* species, *G. sorrentoensis* from Western Australia and *G. daviei* Bacescu and Udrescu, 1982 from the east coast. The former species can be easily distinguished from the latter by the following particular characters: the posterior margin of the carapace is fringed with spine-like filaments and the fifth abdominal somite has an articulated posteromedian process.

Genus *Haplopanus* Kossman, 1880

*Haplopanus indicus* (Hansen, 1910)


Material Examined
Australia: Queensland: 2 ♂ (6.7, 6.8 mm), 3 ♀.
Gastrosaccini mysids from Australia

(all ca. 7.0 mm), Tangalooma, Moreton Is., 5 March 1973, coll. B. Griffiths (WAM 406-95).

Diagnosis
Rostrum subtriangular, shorter than broad. Posterior margin of carapace smooth, dorsolateral slit entirely fused, represented as fold-like line. Fifth abdominal somite smooth posteriorly. Sixth abdominal somite with obtuse, low transverse swelling at anterior dorsal end, elevating as high as level of posterior dorsal margin, thus dorsum delimited by deep groove in lateral aspect. Telson length (from anterior end to base of terminal spine) 2.9-3.1 times basal width, laterally armed with relatively short, somewhat narrowly spaced 8-11 spines, commonly 8-9, including terminal spine; lateral spines, at least in males, barely reaching base of subsequent spine in distal half, except for penultimate. Endopod of male second pleopod commonly uniarticulate. Endopod of male third pleopod rudimentary; exopod usually composed of 3 segments, first segment subequal to length of second, armed with 2 long lateral spines and large oval lobe, latter originating from a point which is basal 1/6–1/5 along length of basal segment; terminal spines moderately short, 1/8 as long as third segment, lash-like seta nearly straight, barbed.

Distribution
This species is recorded in the Indo-West Pacific: north of Madagascar (W.M. Tattersall 1911); India (Pillai, 1965); Philippine-Indonesian region (Hansen 1910; Delsman 1939; W.M. Tattersall 1951; O.S. Tattersall 1960, 1965); South China Sea (Wang and Liu 1987) Ryukyu Islands, south-western Japan (Hansen 1997:704); New South Wales in Australia (W.M. Tattersall 1940).

Remarks
The specimens from Queensland were more or less damaged, but may be assigned to *Haplostyles indicus*. The terminal lash-like seta is consistently barbed in *H. indicus*. This species is similar to the Australian congener *Haplostylus flagelliforma* Panampunnayil, 1997. However, the lateral spines of the telson in *H. indicus* is proportionately long and narrowly spaced, reaching the base of subsequent spine distally, as opposed to more sparsely placed spines, falling far short of that portion in *H. flagelliforma*.

Unlike the list by Panampunnayil (1997, table 1), the male third pleopodal exopod is composed of three segments in specimens from Queensland. The three segmented exopod is also common in the population of south-west Japan, with the basal segment being longer than the second, or nearly subequal length. Furthermore, it is noted for the latter that the endopod of the male second pleopod is composed of 1 or 2 segments.

*Haplostyles indicus* also shows a close resemblance to *H. similis* Panampunnayil, 1997. For distinction of the two species, see “Remarks” under the latter species.

*Haplostyles similis* Panampunnayil, 1997

Material Examined
Australia: Western Australia: 3 d (6.2-6.5 mm), Rottnest Is., 8 June 1962 (WAM 410-95); 1 ovig. 9 (6.8 mm), Pt. Robinson, Nickol Bay, 30 August 1954 (WAM 414-95).

Diagnosis
Rostrum subtriangular, shorter than broad (Figure 2a). Posterior margin of carapace smooth, dorsolateral slit entirely fused, represented as fold-like line (Figure 2b). Fifth abdominal somite smooth posteriorly. Sixth abdominal somite with obtuse, low transverse swelling at anterior dorsal end, elevating as high as level of posterior dorsal margin, consequently dorsum delimited by moderately deep groove in lateral aspect (Figure 2c). Telson length 2.7-2.9 times basal width, laterally armed with rather long, narrowly spaced 10–14 spines including terminal spine, increasing length towards distally (Figure 2d). Endopod of male second pleopod 1 or 2 segmented (Figure 2e). Endopod of male third pleopod rudimentary; exopod composed of 3 segments, first segment subequal to length of second, laterally armed with 2 spines of subequal length and large, oval lobe, latter originating from a point which is basal 1/5–1/4 along length of basal segment; terminal spines moderately long, 1/6 as long as third segment, lash-like seta barbed (Figure 2f, g).

Distribution
*Haplostyles similis* has been recorded from south-west Australia (Panampunnayil 1997). The present occurrence from Nickol Bay suggest *H. similis* to be distributed along the entire coast of Western Australia.

Remarks
*Haplostyles similis* is one of the five species established recently by Panampunnayil (1997) from south-west Australia. This species is very closely allied to *H. indicus*, but can be distinguished by following features: 1) the telson of *H. similis* is proportionately shorter than that in *H. indicus*, being 2.7–2.9 times the length of basal width, as
Figure 2  *Haploptylus similis* Panampunnayil, 1997, ♂ (6.5 mm) from Rottnest Is., Western Australia: a, anterior part of body; b, posterior part of carapace; c, sixth abdominal somite; d, telson; e, second pleopod; f, third pleopod; g, same as figure f, basal part enlarged.
opposed to 2.9 times or more, and 2) the terminal spines of the male third pleopodal exopod is slightly longer than that in the latter species (about 1/6 times length of the third segment vs 1/8). These characters distinguishing the two species, known to me, are rather minor and future study base on more specimens is strongly encouraged, together with those of *H. flagelliforma*.

*Haplostylus multispinosus* Panampunnayil, 1997

![Figure 3](image)

*Haplostylus multispinosus* Panampunnayil, 1997: 1217, figs 9–12.

**Material Examined**

Australia: Western Australia: 2 ♂ (6.0, 6.6 mm), 1 ♀ (5.8 mm), end of Barrow Is., 2 September 1954, tide running (WAM 408-95).

**Diagnosis**

Rostrum subtriangular, with rounded apex, slightly shorter than broad (Figure 3a). Posterdorsal margin of carapace entire, dorsolateral slit fused, indicated as fold-like line (Figure 3b). Sixth abdominal somite with obtusely rounded transverse swelling at anterior dorsal end, elevating just above level of posterior margin, thus dorsum delimited by moderately deep groove in lateral aspect (Figure 3c). Telson length slightly less than 3 times basal width, laterally armed with somewhat narrowly spaced 10–13 spines including terminal spine; distomedial groove barely reaching base of antepenultimate spine (Figure 3d). Male second pleopod with 2 segmented endopod (Figure 3e). Endopod of male third pleopodal rudimentary, exopod composed of 3 segments, first segment with 2 lateral spines, much shorter in proximal, and small triangular lobe present on lateral margin, originating from a point which is basal 1/3–4/9 along length of basal segment; terminal spines 1/4 length of distalmost segment, terminal lash-like seta barbed (Figure 3g, f).

**Distribution**

This species is known from south-west Australia (Panampunnayil 1997). This study exhibited that *H. multispinosus* is distributed on the entire coast of Western Australia.

**Remarks**

*Haplostylus multispinosus* shows the closest affinity to *H. pacificus* (Hansen, 1912). However, *H. multispinosus* is distinguished from *H. pacificus* by following characters: 1) the endopod of the uropod has 13–14 mesial spines in *H. multispinosus*, as opposed to 7–8 spines in *H. pacificus*; 2) the distomedial groove of the telson is proportionately deep, reaching the base of the antepenultimate spine, in stead of extending the penultimate spine, and 3) the terminal segment of the male third pleopodal exopod is slightly narrowing in distal 1/6, with a lash-like seta markedly barbed, in contrast to that segment narrowing abruptly in distal 2/5–1/3, with a lash-like seta not barbed. In addition, *H. multispinosus* tends to have a larger number of spines on the lateral margin of the telson than in *H. pacificus* (10–13, commonly 12, spines, instead of 8–11, commonly 9–10).

*Haplostylus robustus* (Panampunnayil, 1989)


*Gastrosaccus* sp. Dakin and Colefax, 1940: 132, figs 223 and 224.

**Material Examined**

Australia: Western Australia: 1 ♀ (ca. 9 mm, damaged by drying), Rottnest Is., 28 November 1945 (WAM 412-95).

**Diagnosis**

Rostrum obtusely produced anteriorly, shorter than broad. Posterior margin of carapace with reflexed lobe, derived by prolongation of lower part of typical dorsolateral slit. Fifth abdominal somite with sharp posteromedian process. Telson laterally armed with 6 stout spines including distal spine, penultimate spine placed dorsally rather than laterally and distinctly shorter than antepenultimate spine. Exopod of uropod noticeably shorter than endopod.

**Distribution**

Known only in southern Australia below 33°S (Dakin and Colefax 1940; Panampunnayil 1989; Fenton 1990). *Haplostylus robustus* appears to be numerous in the south-west Australian waters, as the species has reported often to produce swarms in surface waters (Panampunnayil 1989).

*Haplostylus queenslandensis* (Bacescu and Udrescu, 1982)

![Figure 4](image)

*Gastrosaccus queenslandensis* Bacescu and Udrescu, 1982: 83, fig. 3.


**Material Examined**

Australia: Queensland: 1 ♂ (7.3 mm), 2 ♀ (6.0,
Figure 3  *Haplostylus multispinosus* Panampunnayil, 1997, ♂ (6.6 mm) from Barrow Is., Western Australia: a, anterior part of body; b, posterior part of carapace; c, sixth abdominal somite; d, telson; e, second pleopod; f, third pleopod; g, same as figure f, basal part enlarged.
Figure 4  *Haplostylus queenslandensis* (Bacescu and Udrescu, 1982), ♂ (7.3 mm) from 73(3), Brisbane, Queensland: a, cephalothorax; b, abdomen; c, anterior part of body; d, posterior part of carapace; e, telson; f, third pleopod.
Diagnosis

Rostrum moderately developed, triangular, with rounded apex (Figure 4c). Posterior margin of carapace with reflexed large lobe, originating from lower part of typical overlapping slit at dorsolateral part (Figure 4a, d). Fifth abdominal somite without posteromedial process (Figure 4b). Sixth abdominal somite with transverse carinate swelling at anterior dorsal end (Figure 4b). Telson length 2.1–2.5 times basal width, laterally armed with 8–9 stout spines including distal spine, penultimate spine much shorter than terminal spine, both spines close-set to each other; distomedial groove 1/10–1/8 as long as telson (Figure 4e). Male pleopods all biramous: first endopod uniarticulate, exopod with 7 segments; second endopod with 6 or 7 segments, exopod 7 or 8 segments, third endopod uniarticulate, exopod with 7 segments, and laterally armed with 3 spines, subterminal segment longer than terminal segment (Figure 4f).

First pleopod of female biramous, exopod about 1/2 length of endopod. Second to fifth pleopods uniramous, rod-like shape.

Distribution

Previously known only from estuarine waters of central eastern coasts of Australia (Bacescu and Udrescu 1982; Greenwood et al. 1991)

Remarks

This species is closely allied to Haplostylus dispar Panampunnayil, 1997, but is distinguished from the latter in having the exopod of the third male pleopod composed of seven articles with three lateral spines, in contrast to having six segments with two lateral spines. The endopod of the male second pleopod is noticeably shorter than the exopod in H. dispar, while both rami are subequal in this species.

Haplostylus queenslandensis also resembles H. australiensis Wooldridge et al., 1992 but differs from the latter in possessing the telson with the terminal and subterminal spines placed close together and the distomedial groove as shallow as 1/10–1/8 of telson length, as opposed to having the subterminal spine separated from the terminal one and the distomedial groove as deep as 1/6–1/5 (see also Wooldridge et al. 1992). Furthermore, H. queenslandensis is distinguished from H. udrescui by the subterminal spine being much smaller than the terminal one.

Haplostylus queenslandensis shows the closest affinity to H. tenuicaudus sp. nov. recorded from Western Australia. Distinguishing features separating the two species are discussed under the “Remarks” of the latter species.

Haplostylus tenuicaudus sp. nov.

Material Examined

Holotype

♂ (7.5 mm), Pt. Robinson, Nickel Bay, Western Australia, Australia, 30 August 1954, coll. K. Sheard (WAM 636–97, ex WAM 414–95).

Paratypes

Australia: Western Australia: 2 ♂ (7.3, 7.6 mm) and 3 ovig. ♀ (6.8–9.1 mm), data same as holotype (WAM 637–97, ex WAM 414–95); 2 ♂ (7.3, 7.5 mm).
Figure 6  *Haplostylus tenuicaudus* sp. nov., holotype ♂ (7.5 mm) from Pt. Robinson, Nickol Bay, Western Australia: a, anterior part of body; b, posterior part of carapace; c, sixth abdominal somite; d, telson; e, uropod; f, eye; g, antennule; h, antenna; i, eighth thoracic limb; j, penis.
end of Barrow Is., 2 September 1954, tide running (WAM 638-97, ex WAM 408-95); 1 ♀ (4.5 mm) and 1 damaged ♂ abdomen, Normalup, 24 October 1976 (WAM 402–95).

Diagnosis

Posterior margin of carapace with large reflexed lobe. Abdomen with fifth somite rounded on posterior margin. Telson about 3 times as long as basal width, laterally armed with 10–14 spines including terminal spine, subterminal spine placed approximate to terminal spine and much smaller than latter, distomedial groove shallow, being 1/10–1/8 length of telson. Third male pleopod with endopod uniariticate, exopod normally composed of 7 segments (3 lateral spines), terminal segment shorter than penultimate, armed distally with 4 spines. First female pleopod with exopod small, scale-shaped, 1/5–2/3 as long as endopod, with 4 spines. First female pleopod with exopod uniarticulate, exopod with 4 or 5 segments. Endopod of third pleopod uniariticate, slightly curving outwardly, laterally armed with 4 setae; exopod long, with 7 normal segments of varying size, extending beyond end of sixth abdominal somite by slightly less than terminal segment, armed with 3 lateral setae and 4 distal setae; sympod with prominent semicircular distal lobe, longer than endopod, partly covering basal segment of exopod. Fourth and fifth pleopods similar in shape, endopod uniariticate, exopod with 4 or 5 segments.

Description

Body moderately robust, about 6.5–9.5 mm in adult (Figure 5).

Carapace with rostrum moderately developed, subtriangular, with rounded apex, lateral margin covering basal part of eyestalk (Figure 6a); posterolateral lobe covering first abdominal somite except for posterior part in males, slightly short in females; posterior margin deeply excavate dorsally, exposing last 2 thoracic segments, with reflexed large lobe as extension of lower margin of typical dorsolateral slit (Figure 6b). Pseudorostrum upturned distally and tapering.

Abdomen smooth, without hairs or folds (Figure 5). Fifth somite rounded posteriorly, without overhanging median process. Sixth somite 1.23–1.31 times as long as fifth, with transverse carinate swelling at anterior dorsal end (Figure 6c). Telson subequal in length with sixth abdominal somite, 2.8–3.1 (average: 3.0) times as long as basal width, laterally armed with 10–14 spines including terminal spine, sharp procurred process present at base of ventral margin; subterminal lateral spine placed close to terminal spine and noticeably shorter than latter; distomedial groove shallow, 1/10–1/8 length of telson, bearing more than 15 spines on mesial margins (Figure 6d). Exopod of uropod longer than endopod, laterally armed with 11–14 stout spines (Figure 6e). Endopod with 6–8 stout ventromesial spines (Figure 6e).

Eye with cornea well pigmented, as wide as eyestalk (Figure 6f). Antennular peduncle with first segment longest, about 3 times as long as second segment, armed with 1 seta distolaterally; second shortest, laterally armed with 2 stout spines; third segment about 2 times as long as second segment, armed with 1 spine near distodorsal part, outer flagellum with oval lobe at base of mesial part in both sexes, slightly smaller in females (Figure 6g). Antennal scale reaching or slightly extending beyond end of second segment of antennular peduncle in males, while falling just short of that segment in females; distolateral spine falling far short of anterior margin of blade, suture present near distal end (Figures 5a, 6h).

Labrum and mouthparts as illustrated (Figure 7a–g).

Basal plates of exopods of second to fourth thoracic limbs with sharp distolateral spine (Figure 7g), entirely rounded in those of fifth to eighth limbs (Figure 6i). Endopod of eighth limb with carpo-propodus composed of 11–13 segments (Figure 6i).

Penis with sharp spine-like process at mid-length of posterior margin in addition to obtuse lobe at distolateral part, laterally armed with 3 spines (Figure 6j).

Male with biramous pleopods (Figure 8a–e). Endopod of first pleopod uniariticate; exopod with 6–7 segments. Endopod of second pleopod with 6–7 segments; exopod 8–9 segments. Endopod of third pleopod uniariticate, slightly curving outwardly, laterally armed with 4 setae; exopod long, with 7 normal segments of varying size, extending beyond end of sixth abdominal somite by slightly less than terminal segment, armed with 3 lateral setae and 4 distal setae; sympod with prominent semicircular distal lobe, longer than endopod, partly covering basal segment of exopod. Fourth and fifth pleopods similar in shape, endopod uniariticate, exopod with 4 or 5 segments.

Female with first pleopod biramous, exopod small, 1/3–2/5 length of endopod, usually unarmed, rarely with terminal seta (Figure 8f). Second to fifth pleopods uniariticate, rod-shaped (Figure 8g).

Distribution

Haploplus tenaciscus is known to be distributed in shallow waters along the Western Australian coast. Along the north-west coast, this species co-occurs with H. multispinosus.

Remarks

This species is characterized by having a reflexed lobe at the posterior margin of the carapace and by the absence of a spine-like process on the fifth abdominal somite. These characters are shared with H. queenslandensis (Bacescu and Udrescu, 1982), H. udrescui Greenwood et al., 1991, H. australiensis Wooldridge et al., 1992, and H. dispar Panampunnayil, 1997, all known from Australia.

The telson with the small penultimate lateral spine placed approximate to the terminal spine readily distinguishes this species from H. udrescui.
Figure 7  Haplostylus tenuicaudus sp. nov., holotype ♂ (7.5 mm) from Pt. Robinson, Nickol Bay, Western Australia: a, labrum; b, mandibles; c, mandibular palp; d, maxillule; e, maxilla; f, endopod of first thoracic limb; g, second thoracic limb.

DISCUSSION

The genus Haplostylus is currently assigned to the species group of Gastroscincus s.l. with a rudimentary or uniarticulate endopod in the male third pleopod (G. normani group), following Fenton (1990), and subsequently Greenwood et al. (1991), Wooldridge et al. (1992) and Panampunnayil (1997).

Although this character shows a certain degree of consistency and also has practical convenience, it is still doubtful whether this separation reflects a natural monophyletic group. The usefulness of uni- or multiarticulation as a separating character is diminished by the presence of intermediate species having a two- or three-segmented endopod, such as Gastroscincus usangi Bacescu, 1975 and G. longifissura Wooldridge, 1978, in which the second segments onwards are reduced considerably in size as compared with other species of Gastroscincus s.s.

On the other hand, it is well known that several species attributable to Haplostylus have a reflexed
lobe (or lappet) on the posterior margin of the carapace in addition to the typical overlapping slit on this margin, which is shared with related genera, such as *Archaemys*, *Bowmaniella*, *Eurobowmaniella*, *Hiella* and *Gastrosaccus* s.s. Regarding the reflexed lobe, two different types of lobes can be recognized on the basis of their origin. One type is derived from an extension of a part of the lobe above the typical dorsolateral slit (type 1), as represented in the Atlantic species (including the Mediterranean). Interestingly, a similar lobe is observed also in some species of *Gastrosaccus* (e.g. *G. sanctus*).

The other type is that formed by a prolongation of the lower lobe of the typical dorsolateral slit (type 2), as represented in Australian *Haplostylius* species. These facts indicate that the genus *Haplostylius* (and also *Gastrosaccus*) has a more complex phylogenetic nature than that has currently recognized. Only revisitional studies of the species of *Gastrosaccus* s.l. will resolve this difficulty. Until that time, I follow Fenton (1990) and the latest authors (Greenwood et al. 1991; Wooldridge et al. 1992; Panampunnayil, 1997).

Key to species of the genus *Haplostyliis* (Species known from Australian waters are indicated with an asterisk)

1. Posterior margin of carapace more or less with extruding lobe, sometimes developed and reflexed anteriorly; typical overlapping slit (or cleft) present or absent .......... 2
   Posterior margin of carapace smooth except for, if present, typical overlapping slit (or cleft) ................................................................. 11

2. Posterior margin of carapace with small lobe, which is not reflexed anteriorly............... *H. bacesculi* Hatzakis, 1977

3. Reflexed lobe derived from extension of upper part of typical dorsolateral slit (type 1 lobe) ................................................................. 3
   Reflexed lobe derived from extension of lower part of typical dorsolateral slit (type 2 lobe) ................................................................. 5

4. Reflexed lobe relatively small, length equal to width ...................... *H. lobatus* (Nouvel, 1951)
   Reflexed lobe relatively long, about twice as long as width ...................... *H. naguilobatus* (Bacescu and Schiecke, 1974)

5. Fifth abdominal somite with postmedian process ........................................ 6
   Fifth abdominal somite without postmedian process ..................................... 7

6. Telson armed laterally with 6 stout spines, subterminal spine placed dorsally, distinctly shorter than terminal spine ......... *H. robustus* (Panampunnayil, 1989)
   (= *H. lattersalli* Fenton, 1990)

7. Distomedial groove of telson shallower than 1/8 of telson length, subterminal lateral spine placed close to terminal spine .......... *H. brisbanensis* (Bacescu and Udrescu, 1982)

8. Subterminal lateral telson spine subequal to length of terminal spine ............. *H. udrescui* Greenwood et al., 1991

9. Telson comparatively long, length about 3 times basal width, armed with 10-14 lateral spines; terminal segment of male third pleopod longer than penultimate .......... *H. leucaurinus* sp. nov.

Telson comparatively short, length less than 2.5 times basal width, armed with 7-9 lateral spines; terminal segment of male third pleopod shorter than penultimate .......... 10

10. Exopod of male third pleopod with 7 segments, armed with 3 lateral spines; endopod of male second pleopod as long as exopod ........... *H. queenslandensis* (Bacescu and Udrescu, 1982)

Exopod of male third pleopod with 6 segments, armed with 2 lateral spines; endopod of male second pleopod much shorter than exopod ....................................................... *H. dispersus* Panampunnayil, 1997

11. Endopod of male third pleopod rudimentary or indistinct ........................................ 12

Endopod of male third pleopod distinct uniarticulate lobe ................................... 17

12. Rostrum well developed, longer than broad; endopod of male second pleopod with more than 3 segments; exopod of male third pleopod with 6 segments, without lateral projection on basal segment ....................................................... *H. parvus* (Hansen, 1910)

Rostrum shorter than broad; endopod of male second pleopod with 1 or 2 segments; exopod of male third pleopod with 3 or 4 segments, with lateral lobe on basal segment ........................................ 13

13. Basal segment of exopod of male third pleopod with short triangular lateral lobe, budding from a point which is basal 1/4-4/9 length along basal segment and falling short of base of proximal lateral spine ...... 14

Basal segment of exopod of male third pleopod with long tube-like lateral lobe, budding from a point which is basal 1/6-1/5 length along basal segment and barely reaching base of proximal lateral spine...... 15

14. Endopod of uropod with 7 or 8 mesial spines; telson laterally armed with 8-11, somewhat sparsely placed spines and distomedial groove reaching level of base of penultimate spine; distal segment of male third pleopodal exopod abruptly narrowing in distal 2/5 and lash-like terminal seta smooth, not barbed .......... *H. pacificus* (Hansen, 1912)

Endopod of uropod with 13-14 mesial spines; telson laterally armed with 10-13 closely spaced, rather long spines and distomedial groove reaching level of distal third spine; distal segment of male third pleopodal
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exopod slightly narrowing in distal 1/6 and lash-like terminal seta barbed ................. *H. multispinosus Panampunayil, 1997

15. Lateral spines of telson extremely sparsely placed, rather short, distal end falling far short of base of subsequent spine except for distal pair both in males and females ............... *H. flagelliforma Panampunayil, 1997

Lateral spines of telson not extremely sparsely placed, distal end reaching to overreaching base of subsequent spine in distal half .... 16

16. Telson length 2.7-2.9 times basal width, laterally armed with long, close-set 10-13 spines, increasing length towards distally, overlapping each other in males and females; terminal spines of exopod of male third pleopod comparatively long, about 1/6 times length of distal segment, terminal lash-like seta barbed ........................................... *H. similis Panampunayil, 1997

Telson length more than 2.9 times of basal width, laterally armed with moderately long, somewhat sparsely placed 8-12 spines, not overlapping each other at least in males; terminal spines of exopod of male third pleopod comparatively short, about 1/8 times length of distal segment ........................................... *H. indicus (Hansen, 1910)

17. Male second pleopod with endopod uniarticulate ....... *H. estafriacus Bacescu, 1973

Male second pleopod with endopod multiarticulate ........................................... 18

18. Sympod of male third pleopod without distinct distal lobe (or apophysis) ........ 19

Sympod of male third pleopod more of less with developed distal lobe (or apophysis) .... .......................... 22

19. Either third or penultimate segment of exopod of male third pleopod slightly swollen near distal end, connected obliquely with subsequent segment ........................................... 20

Exopod of male third pleopod simple, tube-like except for distal segment, connected almost transversely with subsequent segment ........................................... 21

20. Rostrum subacute with rounded apex; exopod of male third pleopod clearly composed of 5 segments .... *H. utthupus Panampunayil, 1997

Rostrum acutely pointed distally; exopod of male third pleopod normally composed of 4 segments ....... *H. bengalensis (Hansen, 1910) (= Gastroscaccus philippinensis W.M. Tattersall, 1951)

21. Endopod of male second pleopod as long as exopod; terminal segment of male third pleopod distinctly swollen near distal end ... *H. parcrythraeus (Nouvel, 1944)

Endopod of male second pleopod much shorter than exopod; terminal segment of male third pleopod not swollen near distal end ..................... H. erythraeus Kossman, 1880

22. Exopod of male third pleopod without lateral setae or spines except for terminal spines; rostrum well produced anteriorly, as long as or more than broad ........................................... *H. pusillus (Coifmann, 1937)

Exopod of male third pleopod with 2-3 lateral setae or spines; rostrum less produced, much shorter than broad ..................... 23

23. Telson with subterminal lateral spine placed separately from terminal spine; penultimate segment of exopod of male third pleopod distinctly swollen distally ................. *H. normani (G.O. Sars, 1877)

Telson with subterminal lateral spine placed close to terminal spine; penultimate segment of exopod of male third pleopod not swollen distally ....... *H. dakini (W.M. Tattersall, 1940)

To date, the genus Haplostylus exhibits the richest species diversity in the Indo-West Pacific region, with 19 of the 24 known species recorded there, suggesting that the area is a main evolutionary ground for the species which possess a rudimentary or uniarticulate endopod in the male third pleopod. No species of the genus has been collected from the western part of the Atlantic and the eastern Pacific Oceans.

The establishment of the new species H. teniucaudus brings the total number of Australian species of Gastroscaccus and Haplostylus to 17, of which G. davieii Bacescu and Udrescu, 1982, and G. sorrentoensis Woolridge and McLachlan, 1986 are the only two representatives of the genus Gastroscaccus. Of these species, the Western Australian fauna includes one Gastroscaccus species (G. sorrentoensis), and seven Haplostylus (H. dispar, H. flagelliforma, H. multispinosus, H. robustus, H. similis, H. utthupus and H. teniucaudus sp. nov.).

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Lice (Insecta: Phthiraptera) from some Australian birds

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Abstract – Published and unpublished records of feather lice collected from 104 species and subspecies of Australian birds are listed. They comprise 141 species and subspecies of lice; a further 59 louse records are listed at the generic level only, but the latter do not necessarily represent different species. A host-parasite list follows the list of lice.

INTRODUCTION
The Australian bird lice are partially known, with only about 400 species recorded and possibly that many again to be discovered (Murray et al., 1990, 1993; Palma and Barker, 1996). Regionally, only the lice of Tasmania are better known than those from other Australian states (Green and Palma, 1991). Here we record the species of lice collected by the senior author from many Australian birds in several States but mostly in Western Australia, during the years 1967 to 1980. A host-parasite list is also included.

MATERIAL AND METHODS
Collecting lice from live birds can be a complicated venture, due to the legal aspect of obtaining permits to handle protected species and to the natural reluctance of many people to traumatise the bird by handling it and applying an insecticide to its plumage. However, the many thousands of birds which die annually on Australian roads and beaches are a very convenient source of lice for potential collectors.

Freshly killed birds, due to road collisions or to storms and other natural causes, were ideal for louse collecting. Ruffling their feathers over a large container or plastic sheet easily dislodged the lice which were picked up with a small brush previously wet with alcohol 70%. Birds which had been dead for some time, even mummified, still harboured lice which were collected in reasonably good condition and were suitable for systematic study. In all cases, a thorough wash of the bird remains further increased the size of the resulting louse sample. All samples were placed in small vials and preserved in alcohol 70% (ethanol or methanol). A label with the scientific name of the bird and field details such as locality, date and name of collector, all written with pencil or Indian ink, was included in the same vial before sending it to a louse expert.

All samples were sent to the Department of Entomology of the British Museum (Natural History), where most of the lice were slide-mounted and identified by T. Clay, C. Lyal and C. Moreby. Subsequently, the junior author identified several specimens which had been left at the generic level by the BM(NH) staff. Lice clearly recognised either as natural stragglers or as contaminants by human agency (see Pilgrim and Palma, 1982: 2) have been excluded from this list. All the louse samples have been deposited in the BM(NH), with a few species which are also kept in the Museum of New Zealand Te Papa Tongarewa (indicated in the list by the acronym MONZ).

The avian classification, ordinal and family sequence and the nomenclature to the species level follow those of Christidis and Boles (1994), while the nomenclature of subspecies follows Condon (1975).

LIST OF LICE

Order PHTHIRAPTERA Haeckel, 1896
Suborder AMBLYCERA Kellogg, 1896
Family LAEMOBOTHRIIDAE Mjöberg, 1910

Genus Laemobothrion Nitzsch, 1818

Laemobothrion (Eulaeinobothrion) atrin (Nitzsch, 1818)

Laemobothrion (Eulaemobothrion) sp.
Family MENOPONIDAE Mjöberg, 1910

Genus Actornithophilus Ferris, 1916

Actornithophilus ceruleus (Timmermann, 1954)  

Actornithophilus hoplopteri (Mjöberg, 1910)  

Genus Menoponidae Mjöberg, 1910

Actornithophilus certileus (Timmermann, 1954)  

Actornithophilus hoplopteri  

Actornithophilus certileus (Timmermann, 1954)  

Genus Aeolophila Packard, 1870

Genus Actornithophilus Ferris, 1916

Actornithophilus hoplopteri (Mjöberg, 1910)  

Genus Menoponidae Mjöberg, 1910

Actornithophilus certileus (Timmermann, 1954)  

Genus Aeolophila Packard, 1870

Genus Actornithophilus Ferris, 1916

Actornithophilus hoplopteri (Mjöberg, 1910)  

Genus Menoponidae Mjöberg, 1910

Actornithophilus certileus (Timmermann, 1954)  

Genus Aeolophila Packard, 1870

Genus Actornithophilus Ferris, 1916

Actornithophilus hoplopteri (Mjöberg, 1910)  

Genus Menoponidae Mjöberg, 1910

Actornithophilus certileus (Timmermann, 1954)  

Genus Aeolophila Packard, 1870

Genus Actornithophilus Ferris, 1916

Actornithophilus hoplopteri (Mjöberg, 1910)  

Genus Menoponidae Mjöberg, 1910

Actornithophilus certileus (Timmermann, 1954)  

Genus Aeolophila Packard, 1870

Genus Actornithophilus Ferris, 1916

Actornithophilus hoplopteri (Mjöberg, 1910)  

Genus Menoponidae Mjöberg, 1910

Actornithophilus certileus (Timmermann, 1954)  
Lice from Australian birds

Genus Eidmanniella Kéler, 1938

Eidmanniella pellucida (Rudow, 1869)


Genus Franciscola Conci, 1942

Franciscola (Franciscola) funerei Price and Beer, 1966


Franciscola (Franciscola) magnifici Price, 1969

ex Calyptorhynchus banksii naso. Western Australia: North Bannister, 14 April 1968.

Franciscola (Franciscola) roseicapillae Price and Beer, 1966


ex Cacatua sanguinea. Western Australia: Exmouth, June 1969; Roebourne, 22 July 1975.

Genus Fletromenopon Carriker, 1954

Fletromenopon (Keamenopon) kalamundae Price, 1969

ex Piirpureicephalus spiriiis. Western Australia: Kalamunda, 26 January 1968.

Heteromenopon (Keamenopon) psittaciim (Le Souef and Bullen, 1902)


Genus Holomenopon Eichler, 1941

Holomenopon lenoxanthum (Burmeister, 1838)

ex Anas superciliosa. Western Australia: Perth, April 1968.

ex Aythya australis. Western Australia: Perth, 17 March 1968.

Genus Heteromenopon Carriker, 1954

Heteromenopon (Keamenopon) kalamundae Price, 1969

ex Purpureicephalus spurius. Western Australia: Kalamunda, 26 January 1968.

Heteromenopon (Keamenopon) psittacum (Le Souéf and Bullen, 1902)


Genus Holomenopon Eichler, 1941

Holomenopon lenoxanthum (Burmeister, 1838)

ex Anas superciliosa. Western Australia: Perth, April 1968.

Genus Holomenopon Eichler, 1941

Holomenopon lenoxanthum (Burmeister, 1838)


Genus Kelerintenopon Conci, 1942

Kelerintenopon (Lorintenopon) galeritae Price and Emerson, 1966


Genus Kelerintenopon Conci, 1942

Kelerintenopon (Lorintenopon) galeritae Price and Emerson, 1966


Kelerintenopon (Lorintenopon) sp.


Genus Myrsidea Waterston, 1915

Myrsidea australiensis australiensis Klockenhoff, 1971


Myrsidea australiensis bennetti Klockenhoff, 1971

ex Corvus bennetti. Western Australia: Latham, March 1967 (MONZ); Geraldton, 28 November 1970.

Myrsidea rustica (Giebel, 1874)


Myrsidea strangeri Clay, 1970

ex Malurus splendens splendid. Western Australia: Dwellingup, 14 April 1968.

Myrsidea sp.

ex Anthochaera carunculata. Western Australia:

*ex Grallina cyanoleuca.* Western Australia: North Dandalup, 31 May 1969.

*ex Rhipidura leucophrys.* Western Australia: Lake Jandakot, 13 April 1969.

*ex Gymnorhina tibicen dorsalis.* Western Australia: Guildford, 1 November 1967; Bushmead, 17 September 1968; Perth, 27 September 1968; Helena Valley, 17 October 1968; Safety Bay, 27 October 1968; Mandurah, 1 December 1968; Pinjarra, 7 December 1968.

*ex Strepera versicolor.* Western Australia: North Bannister, 25 April 1968.


**Genus Piagetiella Neumann, 1906**

*Piagetiella africana* (Bedford, 1931)

*ex Pelecanus conspicillatus.* Western Australia: Perth, 6 January 1968; Pelican Point, 17 November 1968.

**Genus Plegadiphilus Bedfard, 1939**

*Plegadiphilus threskiornis* Bedford, 1939

*ex Threskiornis molucca.* Western Australia: northern region.

**Genus Pseudomenopon Mjöberg, 1910**

*Pseudomenopon australis* Price and Emerson, 1986


*Pseudomenopon concretum* (Piaget, 1880)


*Pseudomenopon pilosum* (Scopoli, 1763)


**Genus Trinoton Nitzsch, 1818**

*Trinoton querquedulae* (Linnaeus, 1758)


*ex Anas rynchotis.* Western Australia: Perth, 1968.

*ex Anas gracilis.* Western Australia: Perth, 23 March 1968; Wanneroo, 1 December 1968.

*ex Malacorhynchos membranaceus.* Western Australia: Lake Yangebup, 29 June 1972.
Lice from Australian birds

ex *Aulhya australis*. Western Australia: Perth, 17 March 1968.

*Anatoecus* sp.

ex *Oxyura australis*. Western Australia: Perth, 8 June 1973; Lake Bibra, 23 August 1971.

ex *Biziura lobata*. Western Australia: Mandurah, 4 April 1969.

Genus *Aquanirmitis* Clay and Meinertzhagen, 1939

*Aquanirmitis* sp.


Genus *Ardeicola* Clay, 1935

*Ardeicola pilgrimi* Tandan, 1972

ex *Egretta novaehollandiae*. Western Australia: Perth, 1970.

Genus *Austrogoniodcs* Harrison, 1915

*Austrogoniodcs concii* (Kéler, 1952)

ex *Eudyptes chrysocome*. Western Australia: Perth, 7 July 1968.

*Austrogoniodcs cristati* Kéler, 1952

ex *Eudyptes chrysocome*. Western Australia: Perth, 7 July 1968.

*Austrogoniodcs metoecus* Clay, 1971

ex *Biziura lobata*. Western Australia: Perth, 10 February 1968; Mandurah, 4 April 1969.

*Austrogoniodcs waterstoni* (Cummings, 1914)

ex *Eudyptula minor novaehollandiae*. Western Australia: Perth, 10 February 1968.

Genus *Brueelia* Kéler, 1936

*Brueelia seniannulata* (Piaget, 1883)


*Brueelia tenus* (Burmeister, 1838)


*Brueelia* sp.

ex *Merops ornatus*. Western Australia: Lesmurdie, 8 November 1967; Kalamunda, January 1968.

ex *Anthochaera carunculata*. South Australia: Port Lincoln, 9 October 1977.


ex *Ponatostomus superciliosus*. South Australia: southern Eyre Peninsula, August 1977.


ex *Strepera versicolor*. Western Australia: North Barnister, 25 April 1968; Gleneagle, 18 May 1968; Barnister, 18 May 1968.


ex *Corvus bennetti*. Western Australia: Latham, March 1967 (MONZ).


ex *Cincloramphus cruralis*. Western Australia: Karratha, 22 July 1975; Tammin, 9 December 1976.

Genus *Campanulotes* Kéler, 1939

*Campanulotes flavus flavus* (Rudow, 1869)

ex *Phaps chalcoleptera*. Western Australia: Binnu, 20 July 1975.

*Campanulotes flavus elegans* (Tendeiro, 1978)


*Campanulotes* sp.


Genus *Carduiceps* Clay and Meinertzhagen, 1939

*Carduiceps zonarius* (Nitzsch (in Giebel), 1866)

ex *Calidris ruficollis*. Western Australia: Perth, 10 August 1967; Quairading, 18 November 1967.

Genus *Cirropthirius* Timmermann, 1953

*Cirropthirius recurvirostrae* (Linnaeus, 1758)


Genus *Coloceras* Taschenberg, 1882

*Coloceras grande* Tendeiro, 1973

ex *Phaps chalcoptera*. Western Australia: Mandurah, 26 December 1967.

*Coloceras* sp.

ex *Phaps elegans*. South Australia: Port Lincoln, 10 October 1977.

ex *Ocyphaps lophotes*. Western Australia:
Genus *Columbicola* Ewing, 1929

*Columbicola angustus* (Rudow, 1869)
- ex *Phaps chalcoptera*. Western Australia: Mandurah, 26 December 1967; Binnu, 20 July 1975.

*Columbicola mckeani* Tendeiro, 1973
- ex *Ocyphaps lophotes*. South Australia: Port Lincoln, 10 October 1977 (MONZ).

*Columbicola tasmauiensis* Tendeiro, 1967
- ex *Phaps elegans*. South Australia: Port Lincoln, 10 October 1977 (MONZ).

*Columbicola* sp.

Genus *Craspedorrhynchus* Keler, 1938

*Craspedorrhynchus* sp.
- ex *Aquila audax*. Western Australia: Highbury, 5 February 1970.

Genus *Cuculoecus* Ewing, 1926

*Cuculoecus laticlypeatus* (Piaget, 1871)
- ex *Cacomantis flabelliformis*. Western Australia: Perth, June 1970.

*Cuculoecus* sp.

Genus *Degeeriella* Neumann, 1906

*Degeeriella eluari* Tendeiro, 1955

*Degeeriella falva* (Giebel, 1874)
- ex *Hieracetus morphmoides*. Western Australia: Pilbara, 29 June 1969.

*Degeeriella fusca* (Denny, 1842)

*Degeeriella rafa rafa* (Burmeister, 1838)
- ex *Falco berigora*. Western Australia: Perth, 10 February 1968.
- ex *Falco longipennis*. Western Australia: Perth, 13 April 1968.

Genus *Docophoroides* Giglioli, 1864

*Docophoroides simplex* (Waterston, 1914)
- ex *Diomedea melanophris*. Western Australia: Mandurah, 3 August 1968; Perth, 4 October 1970 (MONZ).


Genus *Echinophilopterus* Ewing, 1927

*Echinophilopterus angustoclypeatus* (Piaget, 1880)

Genus *Emersoniella* Tendeiro, 1965

*Emersoniella bracteata* (Nitzsch (in Giebel), 1866)

Genus *Forficulococcus* Conci, 1941

*Forficulococcus forficula* (Piaget, 1871)
- ex *Psophotus haematotus*. Victoria: Hopeville, 1 April 1980 (MONZ).

*Forficulococcus palmai* Guimarães, 1985

Genus *Fulicoffula* Clay and Meinertzhagen, 1938

*Fulicoffula lurida* (Nitzsch, 1818)

*Fulicoffula* sp.

Genus *Goniodes* Nitzsch, 1818

*Goniodes fissus* (Rudow, 1869)

*Goniodes* sp.

Genus *Halipeurus* Thompson, 1936

*Halipeurus (Halipeurus) mirabilis* Thompson, 1940
Lice from Australian birds

*Halipeurus (Synnantes) pelagicus* (Denny, 1842)  
ex *Pelagodroma marina.* Western Australia: Perth, 29 December 1968.

*Halipeurus (Halipeurus) placodus* Edwards, 1961  
ex *Puffinus assimilis tunneyi.* Western Australia: Becher Point, 4 October 1970.

*Halipeurus (Halipeurus) procellariae* (J.C. Fabricius, 1775)  
ex *Pterodroma macroptera.* Western Australia; Perth, 14 December 1969.

*Halipeurus* (Halipeurus) *placodtis* Edwards, 1961  
ex *Puffinus assimilis tunneyi.* Western Australia: Becher Point, 4 October 1970.

*Halipeurus* (Halipeurus) *procellariae* (J.C. Fabricius, 1775)  
ex *Pterodroma macroptera.* Western Australia; Perth, 29 December 1968.

*Genus Incidifrons* Ewing, 1929  

*I. futilicae* (Linnaeus, 1758)  

*Genus Lipeuris* Nitzsch, 1818  

*L. crassiis* Rudow, 1869  

*Genus Lioptilacta* Clay and Meinertzhagen, 1939  

*L. drosti* Timmermann, 1954  
ex *Calidris tenuirostris.* Western Australia: Mandurah, 7 February 1970.

*Lioptilacta* sp.  
ex *Calidris ruficollis.* Western Australia: Perth, 10 August 1967; Quairading, 18 November 1967.

*Genus Meropoces* Eichler, 1940  

*Meropoces* sp.  
ex *Merops ornatus.* Western Australia: Lesmurdie, 8 November 1967; Kalamunda, January 1968.

*Genus Multicola* Clay and Meinertzhagen, 1938  

*Multicola* sp.  
ex *Eurostopodus argus.* Western Australia: Mount Goldsworthy, 23 July 1975.

*Genus Naubates* Bedford, 1930  

*Naubates futilinosus* (Taschenberg, 1882)  

*Naubates harrisoni* Bedford, 1930  
ex *Puffinus pacificus.* Western Australia: Perth, 14 May 1969.  
ex *Puffinus assimilis tunneyi.* Western Australia: Becher Point, 4 October 1970.

*Naubates heteroproctus* Harrison, 1937  
ex *Pterodroma macroptera.* Western Australia: Perth, 14 December 1969.

*Naubates prioni* (Enderlein, 1908)  
ex *Pachyptila salviini.* Western Australia: Mandurah, 25 July 1970.  
ex *Pachyptila desolata.* Western Australia: Mullaloo Beach, 29 June 1968; Mandurah, 3 August 1968; Warraboro Sound, 29 June 1970; Perth, 29 August 1972; Swanbourne Beach, 30 July 1973.  
ex *Pachyptila belcheri.* Western Australia: Mandurah, 28 July 1968; Perth, 30 July 1968.  

*Naubates pterodromi* Bedford, 1930 subspecies  
ex *Pterodroma lessonii.* Western Australia: Perth, June 1970.

*Genus Neopsittaconinus* Conci, 1942  

*Neopsittaconinus borgiolii* Conci, 1942  
ex *Calyptorhynchus banksii naso.* Western Australia: North Bannister, 14 April 1968.  

*Neopsittaconinus circumfasciatus* (Piaget, 1880)  
ex *Platycercus elegans.* Victoria: Dunkeld, 1 April 1980 (MONZ).  
ex *Barnardius zonarius semitorquatus.* Western Australia: Mandurah, 8 January 1971.

*Neopsittaconinus eos* (Giebel, 1874)  
ex *Cacatua sanguinea.* Western Australia: Exmouth, June 1969.

*Neopsittaconinus* sp.  
ex *Nymplicicus hollandicus.* Western Australia: Perth, 11 August 1968.  
ex *Peripureicephalus spirius.* Western Australia: Perth, 30 August 1974.

*Genus Oxylipeuris* Mjöberg, 1910  

*Oxylipeuris ischioccephalus* (Taschenberg, 1882)  

*Genus Paraclisis* Timmermann, 1965  

*Paraclisis diomedae* (J.C. Fabricius, 1775)  
ex *Dionoea melanophris.* Western Australia: Perth,
4 October 1970 (MONZ); Mandurah, 3 August 1968.


ex *Diomedia chlororhyynchos*. Western Australia: Perth, June 1970.

ex *Phoebetria fusca*. Western Australia: Rockingham, 2 August 1968.

*Paraclisis obscura* (Rudow, 1869)

ex *Macronectes giganteus*. Western Australia: Perth, 7 July 1968.

Genus *Pectinopygia* Mjoberg, 1910

*Pectinopygia australis* Thompson, 1948

ex *Pelecanus conspicillatus*. Western Australia: Perth, 6 January 1968; Pelican Point, 17 November 1968.

*Pectinopygia dispar* (Piaget, 1880)


*Pectinopygia setosus* (Piaget, 1880)

ex *Phalarocorax sulphuricollis*. Western Australia: Perth, 13 November 1969.

*Pectinopygia varius* Timmermann, 1964


Genus *Penenirnii* Clay and Meinertzhagen, 1938

*Penenirnii* sp.

ex *Anthus novaesanclandiae*. Western Australia: Northam, 4 September 1976.

Genus *Perineius* Thompson, 1936

*Perineius circumfasciatus* Kéler, 1957

ex *Diomedia melanophris*. Western Australia: Perth, 4 October 1970; Mandurah, 3 August 1968.

*Perineius nigroilimbatus* (Grieb, 1874)

ex *Lophornis glacioloides*. Western Australia: Perth, 1968 (MONZ); Scarborough Beach, 25 August 1968.

Genus *Philopteris* Nitzsch, 1818

*Philopteris ecbicus microsomaticus* Tandan, 1955


*Philopteris* sp.

ex *Acanthiza chrysocephala*. Western Australia: Perth, 1 October 1967.

ex *Anthochaera carunculata*. Western Australia: Perth, 3 October 1970, 18 December 1970;

R.H. Stranger, R.L. Palma


ex *Grallina cyanoleuca*. Western Australia: Rockingham, 3 August 1968.


ex *Strepera versicolor*. Western Australia: North Bannister, 25 April 1968; Glenelg, 18 May 1968; Bannister, 18 May 1968.


ex *Corvus candidatus*. Western Australia: Latham, March 1967; Geraldton, 28 November 1969.


Genus *Physconelloides* Ewing, 1927

*Physconelloides australiensis* Tendeiro, 1969

ex *Phaps chalcoptera*. Western Australia: Binnu, 20 July 1975.

ex *Phaps elegans*. South Australia: Port Lincoln, 10 October 1977.

*Physconelloides straegeri* Tendeiro, 1980


Genus *Podargocciis* Emerson and Price, 1966

*Podargocciis strigoides* Emerson and Price, 1966


*Podargocciis tasmanianus* Price, 1976


Genus *Pseiidonirnii* Mjoberg, 1910

*Pseiidonirnii* gurlti (Taschenberg, 1882)

Lice from Australian birds

**Genus Psittoecus Conci, 1942**

*Psittoecus cos* (Rudow, 1869)
- ex *Cacatua sanguinea*. Western Australia: Exmouth, June 1969; Roebourne, 22 July 1975.

*Psittoecus sp.*
- ex *Calyptorhynchus banksii naso*. Western Australia: North Bannister, 14 April 1968.

**Genus Quadraceps Clay and Meinertzhagen, 1939**

*Quadraceps australis Emerson and Price, 1986*
*Quadraceps bicuspis dressleri* Timmermann, 1971
- ex *Elseyornis melanops*. Western Australia: Perth, 7 April 1968.
*Quadraceps charadrii hospes* (Nitzsch (in Giebel), 1866)
*Quadraceps decipiens* (Denny, 1842)
*Quadraceps hopkinsi hopkinsi* Timmermann, 1952
*Quadraceps legatus* Timmermann, 1952
*Quadraceps neoanadrus Emerson and Price, 1986*
- ex *Chlaradrius australis*. Western Australia: Cuc, 23 August 1974.
*Quadraceps nycthemerus* (Burmeister, 1838)
- ex *Sterna nereis*. Western Australia: Pelican Point, January 1967.
*Quadraceps punctatus lingulatus* (Waterston, 1914)
*Quadraceps rensci Timmermann, 1954*

**Genus Rallicola Johnston and Harrison, 1911**

*Rallicola bournei Price and Emerson, 1986*

*Rallicola fulicae* (Denny, 1842)

*Rallicola lugens* (Giebel, 1874)

**Genus Saemundssonia Timmermann, 1936**

*Saemundssonia (Saemundssonia) africana sycophanta* Timmermann, 1962
*Saemundssonia (Saemundssonia) bicolor* (Rudow, 1870)
- ex *Fulmarus glacialoides*. Western Australia: Perth, 25 August 1968 (MONZ).
*Saemundssonia (Saemundssonia) conica naumanni* (Giebel, 1874)
*Saemundssonia (Saemundssonia) desolata* Timmermann, 1959
- ex *Pachyptila belcheri*. Western Australia: Mandurah, 28 July 1968; Perth, 30 July 1968.
Saemundssonia (Saemundssonia) lari (O. Fabricius, 1780)

Saemundssonia (Saemundssonia) laticaudata (Rudow, 1869)
ex Sterna bergii. Western Australia: Perth, 1 June 1968; Mandurah, 18 August 1968.

Saemundssonia (Saemundssonia) lockleyi Clay, 1949
ex Sterna anaethetus. Western Australia: Perth, 4 October 1970.

Saemundssonia (Saemundssonia) melanocephalus (Burmeister, 1838)
ex Sterna nereis. Western Australia: Pelican Point, January 1967.

Saemundssonia (Saemundssonia) meridiana Timmermann, 1950
ex Sterna anaethetus. Western Australia: Perth, 4 October 1970.

Saemundssonia (Saemundssonia) minitrans Timmermann, 1977
ex Malacorhynchus membranaceus. Western Australia: Lake Yangebup, 29 July 1972.

Saemundssonia (Saemundssonia) stammeri Timmermann, 1959

Saemundssonia (Saemundssonia) tringae sibiriae Martens, 1974
ex Calidris tenuirostris. Western Australia: Mandurah, 7 February 1970.

Saemundssonia (Saemundssonia) tringae tringae (O. Fabricius, 1780)
ex Calidris ruficollis. Western Australia: Perth, 10 August 1967; Quairading, 18 November 1967.

Saemundssonia sp.

Genus Strigiphilus Mjöberg, 1910

Strigiphilus aitkeni Clay, 1966

Strigiphilus rapidus Clay, 1977

Genus Trabeculus Rudow, 1866

Trabeculus hexakon (Waterston, 1914)
ex Puffinus pacificus. Western Australia: Perth, 14 May 1969.

Trabeculus schillingi Rudow, 1866

Genus Turnicola Clay and Meinertzhagen, 1938

Turnicola sp.
ex Turnix vari. Western Australia: Perth, 31 October 1970.

HOST – PARASITE LIST

Class AVES

Order GALLIFORMES

Family MEGAPODIIDAE

Genus Alectura Latham, 1824

Alectura lathami Gray, 1831 Brush-turkey
Goniodes fissus (Rudow, 1869)
Goniodes sp.
Lipeimis crassus Rudow, 1869
Oxylipurus ischnocephalus (Taschenberg, 1882)

Order ANSERIFORMES

Family ANATIDAE

Genus Oxyura Bonaparte, 1827

Oxyura australis Gould, 1836 Blue-billed Duck
Anaticola sp.
Anatoecus icterodes icterodes (Nitzsch, 1818)
Anatoecus sp.

Genus Biziura Stephens, 1824

Biziura lobata (Shaw, 1796) Musk Duck
Anaticola sp. (nymphs only)
Anatoecus sp. (females only)
Austrogoniodes metoecus Clay, 1971
Lice from Australian birds

Genus *Anas* Linnaeus, 1758

*Anas superciliosa* Gmelin, 1789

Pacific Black Duck

*Anaticola crassicornis crassicornis* (Scopoli, 1763)
*Anatocercus icterodes icterodes* (Nitzsch, 1818)
*Holomenopon leucoxanthum* (Burmeister, 1838)
*Trinoton querquedulæ* (Linnaeus, 1758)

Genus *Anas* Latham, 1801

*Anas rhynchotis* Latham, 1801

Australasian Shoveler

*Anaticola crassicornis crassicornis* (Scopoli, 1763)
*Anatocercus icterodes icterodes* (Nitzsch, 1818)
*Trinoton querquedulæ* (Linnaeus, 1758)

Genus *Anas* gracilis Buller, 1869

Grey Teal

*Anaticola crassicornis crassicornis* (Scopoli, 1763)
*Trinoton querquedulæ* (Linnaeus, 1758)

Genus *Malacorhynchos* Swainson, 1831

*Malacorhynchos membranaceus* (Latham, 1801)

Pink-eared Duck

*Anaticola crassicornis crassicornis* (Scopoli, 1763)
*Trinoton querquedulæ* (Linnaeus, 1758)

Genus *Aythya* Boie, 1822

*Aythya australis* (Eyton, 1838)

White-eyed Duck

*Anaticola crassicornis eytonti* (Rudow, 1870)
*Trinoton querquedulæ* (Linnaeus, 1758)

Order PODICIPEDIFORMES

Family PODICIPEDIDAE

Genus *Poliocephalus* Selby, 1840

*Poliocephalus poliocephalus* (Jardine and Selby, 1827)

Hoary-headed Grebe

*Aquanirmus* sp.

Order SPHENISCIFORMES

Family SPHENISCIDAE

Genus *Eudyptes* Vieillot, 1816

*Eudyptes chrysocephalus* (Forster, 1781)

Rockhopper Penguin

*Austrogoniodes concii* (Kéler, 1952)
*Austrogoniodes cristati* Kéler, 1952

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Genus *Eudyptula* Bonaparte, 1856

*Eudyptula minor novachollandiae* (Stephens, 1826)

Little Penguin

*Austrogoniodes waterstoni* (Cummings, 1914)

Order PROCELLARIIFORMES

Family PROCELLARIIDAE

Genus *Macronectes* Richmond, 1905

*Macronectes giganteus* (Gmelin, 1798)

Southern Giant-petrel

*Paraclisis obscura* (Rudow, 1869)

Genus *Fulmarus* Stephens, 1826

*Fulmarus glacialis* (Smith, 1840)

Southern Fulmar

*Austrogoniodes popellus* (Piaget, 1890)

*Nauibates heteroproctus* Harrison, 1937

*Trabeculus schillingi* Rudow, 1866

*Pterodroma lessonii* (Garnot, 1826)

*Pterodroma macroptera* (Smith, 1840)

Great-winged Petrel

*Austrogoniodes concii* (Kéler, 1952)

*Nauibates pterodromi* Bedford, 1930 subspecies

*Trabeculus schillingi* Rudow, 1866

*Pterodroma mollis* (Gould, 1844)

Soft-plumaged Petrel

*Halipeiliis (Halipeiliis) procellariae* (J.C. Fabricius, 1775)

*Trabeculus schillingi* Rudow, 1866

*Pterodroma lessonii* (Garnot, 1826)

White-headed Petrel

*Halipeiliis (Halipeiliis) procellariae* (J.C. Fabricius, 1775)

*Trabeculus schillingi* Rudow, 1866

*Pterodroma mollis* (Gould, 1844)

Soft-plumaged Petrel

*Halipeiliis (Halipeiliis) procellariae* (J.C. Fabricius, 1775)

Genus *Pachyptila* Illiger, 1811

*Pachyptila salvini* (Mathews, 1912) Salvin’s Prion

*Nauibates priou* (Enderlein, 1908)
**Saemundssonia (Saemundssonia) desolata**
Timmermann, 1959

**Pachyptila desolata** (Gmelin, 1789) Antarctic Prion

**Austromonopon vagelli** (J.C. Fabricius, 1787)
**Austromonopon stammeri** Timmermann, 1963
**Naubates prieni** (Enderlein, 1908)
**Saemundssonia (Saemundssonia) desolata** Timmermann, 1959

**Pachyptila belcheri** (Mathews, 1912)
Slender-billed Prion

**Ancistrona vagelli** (J.C. Fabricius, 1787)
**Ancistrona timidus** Timmermann, 1963
**Naubates prieni** (Enderlein, 1908)
**Saemundssonia (Saemundssonia) desolata** Timmermann, 1959

**Pachyptila turtur** (Kuhl, 1820)
Fairy Prion

**Ancistrona vagelli** (J.C. Fabricius, 1787)
**Ancistrona timidus** Timmermann, 1963
**Naubates prieni** (Enderlein, 1908)
**Saemundssonia (Saemundssonia) desolata** Timmermann, 1959

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**Genus Procellaria Linnaeus, 1758**

**Procellaria aequinoctialis** Linnaeus, 1758
White-chinned Petrel

**Austromonopon popellius** (Piaget, 1890)
**Naubates fuidginosus** (Taschenberg, 1882)
**Trabeclius hexon** (Waterston, 1914)

**Genus Puffinus Brisson, 1760**

**Puffinus pacificus** (Gmelin, 1789)
Wedge-tailed Shearwater

**Austromonopon pauluhn** (Kellogg and Chapman, 1899)
**Halipeurus (Halipeurus) mirabilis** Thompson, 1940
**Naubates harrisoni** Bedford, 1930
**Trabeclius hexon** (Waterston, 1914)

**Puffinus assimilis tunneyi** Mathews, 1912
Little Shearwater

**Halipeurus (Halipeurus) placolus** Edwards, 1961
**Naubates harrisoni** Bedford, 1930

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**Family DIOMEDEIDAE**

**Genus Diomedea Linnaeus, 1758**

**Diomedea melanophris** Temminck, 1828
Black-browed Albatross

**Austromonopon navius** (Kellogg, 1896)
**Docophoroides simplex** (Waterston, 1914)
**Paraclisis diomedae** (J.C. Fabricius, 1775)
**Perneus circumfasciatus** Keler, 1957
**Diomedea chrysostoma** Forster, 1785
Grey-headed Albatross

**Austromonopon pinguis** (Kellogg, 1896)

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**Family PHALACROCORACIDAE**

**Genus Phalacrocorax Brisson, 1760**

**Phalacrocorax melanoleucos** (Vieillot, 1817)
Little Pied Cormorant

**Pectinopgus dispar** (Piaget, 1880)
**Phalacrocorax varius** (Gmelin, 1789)
Pied Cormorant

**Eidmanniella pallidella** (Rudow, 1869)
**Pectinopgus varius** Timmermann, 1964
**Phalacrocorax sulcirostris** (Brandt, 1837)
Little Black Cormorant

**Pectinopgus setosus** (Piaget, 1880)

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**Family PELECANIDAE**

**Genus Pelecanus Linnaeus, 1758**

**Pelecanus conspicillatus** Temminck, 1824
Australian Pelican

**Colpocephalum exsul** Burmeister, 1838
**Pelecanus conspicillatus** Temminck, 1824
**Pelecanus conspicillatus** Temminck, 1824

**Piagetella africana** (Bedford, 1931)

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**Order CICONIIFORMES**

**Family ARDEIDAE**

**Genus Erythrogonus Forster, 1817**

**Erythrogonus conspicillatus** Temminck, 1824
**Erythrogonus conspicillatus** Temminck, 1824

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**Family PELECANIDAE**

**Genus Pelecanus Linnaeus, 1758**

**Pelecanus conspicillatus** Temminck, 1824
**Pelecanus conspicillatus** Temminck, 1824

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**Order CICONIIFORMES**

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**Family ARDEIDAE**

**Genus Erythrogonus Forster, 1817**

**Erythrogonus conspicillatus** Temminck, 1824
**Erythrogonus conspicillatus** Temminck, 1824

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**Family PELECANIDAE**

**Genus Pelecanus Linnaeus, 1758**

**Pelecanus conspicillatus** Temminck, 1824
**Pelecanus conspicillatus** Temminck, 1824

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**Order CICONIIFORMES**

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**Family ARDEIDAE**

**Genus Erythrogonus Forster, 1817**

**Erythrogonus conspicillatus** Temminck, 1824
**Erythrogonus conspicillatus** Temminck, 1824

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**Family PELECANIDAE**

**Genus Pelecanus Linnaeus, 1758**

**Pelecanus conspicillatus** Temminck, 1824
**Pelecanus conspicillatus** Temminck, 1824

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**Order CICONIIFORMES**

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**Family ARDEIDAE**

**Genus Erythrogonus Forster, 1817**

**Erythrogonus conspicillatus** Temminck, 1824
**Erythrogonus conspicillatus** Temminck, 1824

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**Family PELECANIDAE**

**Genus Pelecanus Linnaeus, 1758**

**Pelecanus conspicillatus** Temminck, 1824
**Pelecanus conspicillatus** Temminck, 1824
Lice from Australian birds

Family THRESKIORNITHIDAE
Genus *Threskiornis* Gray, 1842
*Threskiornis molucca* (Cuvier, 1829)  
*Australian White Ibis*  
-Colpoccephalus aethiopicus* Price and Beer, 1965  
*Plegadiphitus threskiornis* Bedford, 1939

Order FALCONIFORMES
Family ACCIPITRIDAE
Genus *Elanus* Savigny, 1809
*Elanus axillaris* (Latham, 1801)  
*Black-shouldered Kite*  
*Degeeriella elani* Tendeiro, 1955

Genus *Circus* Lacépède, 1799
*Circus approximans* Peale, 1848  
*Swamp Harrier*  
*Degeeriella fusca* (Denny, 1842)

Genus *Aquila* Brisson, 1760
*Aquila audax* (Latham, 1801)  
*Wedge-tailed Eagle*  
*Crasedorrhynchus* sp.

Genus *Hieraaetus* Kaup, 1844
*Hieraaetus morphnoides* (Gould, 1841) *Little Eagle*  
*Degeeriella fulva* (Giebel, 1874)

Family FALCONIDAE
Genus *Falco* Linnaeus, 1758
*Falco berigora* Vigors and Horsfield, 1827  
*Brown Falcon*  
*Degeeriella rufa rufa* (Burmeister, 1838)

*Falco longipennis* Swainson, 1837  
*Australian Hobby*  
*Degeeriella rufa rufa* (Burmeister, 1838)

*Falco cenchroides* Vigors and Horsfield, 1827  
*Nankeen Kestrel*  
*Degeeriella rufa rufa* (Burmeister, 1838)

Order GRUIIFORMES
Family RALLIDAE
Genus *Gallirallus* Lafresnaye, 1841
*Gallirallus philippensis australis* (von Pelzeln, 1873)  
*Buff-banded Rail*  
*Rallcota ortygometra philippensis* Emerson, 1966

Genus *Porphyrio* Brisson, 1760
*Porphyrio porphyrio bellus* Gould, 1840  
*Purple Swamphen*  
*Laemobothrion (Eulaemobothrion) sp. (nymphs only)*

*Pseudomenopon concretrum* (Piaget, 1880)  
*Rallcota ingens* (Giebel, 1874)

Genus *Gallinula* Brisson, 1760
*Gallinula ventralis* Gould, 1837  
*Black-tailed Native-hen*  
*Falicofida sp.*  
*Pseudomenopon australis* Price and Emerson, 1986  
*Rallcota bournei* Price and Emerson, 1986

Genus *Falica* Linnaeus, 1758
*Falica atra australis* Gould, 1845  
*Australasian Coot*  
*Laernobothrion (Fulaemobothrion) sp. (nymphs only)*  
*Pseudomenopon australis* Price and Emerson, 1986  
*Rallcota bournei* Price and Emerson, 1986

Order TURNICIFORMES
Family TURNICIDAE
Genus *Turnix* Bonnaterre, 1791
*Turnix varia* (Latham, 1801)  
*Painted Button-quail*  
*Turnicola* sp.

Order CHARADRIIFORMES
Family SCOLOPACIDAE
Genus *Calidris* Merrem, 1804
*Calidris tenuirostris* (Horsfield, 1821)  
*Great Knot*  
*Actornithophilus* sp. (nymphs only)  
*Lunaceps drosti* Timmermann, 1954  
*Saemundssonia (Saemundssonia) tringae sibiriae* Martens, 1974  
*Calidris ruficollis* (Pallas, 1776)  
*Red-necked Stint*  
*Actornithophilus* sp. (nymphs only)  
*Carduiceps zonarius* (Nitzsch (in Giebel), 1866)  
*Lunaceps sp.*  
*Saemundssonia (Saemundssonia) tringae tringae* (O. Fabricius, 1780)

Family RECURVIROSTRIDAE
Genus *Recurvirostra* Linnaeus, 1758
*Recurvirostra novaehollandiae* Vieillot, 1816  
*Red-necked Avocet*  
*Austromenopon micrandum* (Nitzsch (in Giebel), 1866)
Family CHARADRIIDAE

Genus Charadrius Linnaeus, 1758
Charadrius australis (Gould, 1841) Inland Dotterel
Austromenopon sp.
Quadraceps australis Emerson and Price, 1986

Genus Elseyornis Mathews, 1914
Elseyornis melanops (Vieillot, 1818) Black-fronted Dotterel
Quadraceps bicuspis dressleri Timmermann, 1971

Genus Vanellus Brisson, 1760
Vanellus tricolor (Vieillot, 1818) Banded Lapwing
Actornithophilus hoplopteri (Mjöberg, 1910)
Quadraceps australis Emerson and Price, 1986
Saemundssonia sp.

Vanellus miles novaehollandiae Stephens, 1819
Masked Lapwing
Actornithophilus hoplopteri (Mjöberg, 1910)
Austromenopon acjaliitisid (Durrant, 1906)
Quadraceps renshi Timmermann, 1954
Saemundssonia (Saemundssonia) africana sycophanta Timmermann, 1962

Family LARIDAE

Genus Larus Linnaeus, 1758
Larus novaehollandiae novaehollandiae Stephens, 1826
Silver Gull
Actornithophilus picus lari (Packard, 1870)
Austromenopon transversum (Denny, 1842)
Quadraceps punctatus liuidatus (Waterston, 1914)
Saemundssonia (Saemundssonia) lari (O. Fabricius, 1780)

Genus Sterna Linnaeus, 1758
Sterna bergii Lichtenstein, 1823 Crested Tern
Actornithophilus picus picus (Denny, 1842)
Austromenopon atrofulvum (Piaget, 1880)

Quadraceps sellatus (Burmeister, 1838)
Saemundssonia (Saemundssonia) laticeps (Rudow, 1869)

Sterna nereis (Gould, 1843) Fairy Tern
Quadraceps nycthemerus (Burmeister, 1838)
Saemundssonia (Saemundssonia) melanocephalus (Burmeister, 1838)
Sterna antarctica Scopoli, 1786 Bridled Tern
Austromenopon atrofulvum (Piaget, 1880)
Quadraceps legatus Timmermann, 1952
Saemundssonia (Saemundssonia) lockleyi Clay, 1949
Saemundssonia (Saemundssonia) meridiana Timmermann, 1950

Genus Anous Stephens, 1826
Anous tenuirostris (Temminck, 1823) Lesser Noddy
Actornithophilus ceruleus (Timmermann, 1954)
Quadraceps hopkinsi hopkinsi Timmermann, 1952

Order COLUMBIFORMES

Family COLUMBIDAE

Genus Phaps Selby, 1835
Phaps chalcoptera (Latham, 1790) Common Bronzewing
Campanulotes flavus flavus (Rudow, 1869)
Coloceras sp.
Columbicola angustus (Rudow, 1869)
Physconeloides australiensis Tendeiro, 1969
Physconeloides strangleri Tendeiro, 1980
Phaps elegans (Temminck, 1810) Brush Bronzewing
Campanulotes flavus elegans (Tendeiro, 1978)
Coloceras sp.
Columbicola tasmaniensis Tendeiro, 1967
Physconeloides australiensis Tendeiro, 1969

Genus Ocyphaps Gray, 1842
Ocyphaps lophotes (Temminck and Laugier, 1822) Crested Pigeon
Campanulotes sp.
Coloceras sp.
Columbicola meekowi Tendeiro, 1973

Genus Geophaps Gray, 1842
Geophaps plumifera Gould, 1842 Spinifex Pigeon
Coloceras sp.
Columbicola sp.
Lice from Australian birds

Order PSITTACIFORMES
Family CACATUIDAE
Genus Calyptorhynchus Desmarest, 1826
  Calyptorhynchus banksii naso (Gould, 1837) Red-tailed Black Cockatoo
  Franciscoa (Franciscola) magnifici Price, 1969
  Neopsittaconirrus borgioli Conci, 1942
  Psittoecus sp.
Genus Calyptorhynchus latirostris Carnaby, 1948
  Franciscoa (Franciscola) funerei Price and Beer, 1966
  Kelerimenopon (Lorimenopon) sp. (females only)
  Neopsittaconirrus borgioli Conci, 1942
  Psittoecus sp.
Genus Cacatua Vieillot, 1817
  Cacatua roseicapilla Vieillot, 1817 Galah
  Franciscoa (Franciscola) roseicapillae Price and Beer, 1966
  Kelerimenopon (Lorimenopon) galerita Price and Emerson, 1966
  Neopsittaconirrus eos (Giebel, 1874)
  Psittoecus eos (Rudow, 1869)
Genus Nymphicus Wagler, 1832
  Nymphicus hollandicus (Kerr, 1792) Cockatiel
  Neopsittaconirrus sp.
Family PSITTACIDAE
Genus Polytelis Wagler, 1832
  Polytelis anthopeplus (Lear, 1831) Regent Parrot
  Echinophilopterus angustoclypeatus (Piaget, 1880)
  Neopsittaconirrus circumpacius Waterhouse, 1877
Genus Platycercus Vigors, 1826
  Platycercus elegans (Gmelin, 1788) Crimson Rosella
  Heteromenopon (Keamenopon) psittacinus (Le Souëf and Bullen, 1902)
  Neopsittaconirrus circumpacius (Piaget, 1880)
Genus Barnardius Bonaparte, 1854
  Barnardius zonarius semitorquatus (Quoy and Gaimard, 1830) Australian Ringneck
  Forficulocetus palmii Guimarães, 1985
Genus Purpureicephalus Bonaparte, 1854
  Purpureicephalus spurius Kuhl, 1820 Red-capped Parrot
  Forviculus palmae Guimarães, 1985
  Heteromenopon (Keamenopon) kalamandia Price, 1969
  Neopsittaconirrus sp.
Genus Psephotus Gould, 1845
  Psephotus haematotus (Gould, 1838) Red-rumped Parrot
  Forviculus forficula (Piaget, 1871)

Order CUCULIFORMES
Family CUCULIDAE
Genus Cuculus Linnaeus, 1758
  Cuculus pallidus Latham, 1801 Pallid Cuckoo
  Cuculophiliis (Cuculophiliis) fasciatus Scopoli, 1763
  Cuculopsis sp.
Genus Cacomantis Müller, 1843
  Cacomantis flabelliformis Latham, 1801 Fan-tailed Cuckoo
  Cuculopsis latichyleptus (Piaget, 1871)

Order STRIGIFORMES
Family STRIGIDAE
Genus Ninox Hodgson, 1837
  Ninox novaeseelandiae (Gmelin, 1788) Southern Boobook
  Kiirodaia cryptostigmatia (Nitzsch, 1861)
  Strigiphiliis vapidiis Clay, 1977
Family TYTONIDAE
Genus Tyto Billberg, 1828
  Tyto alba delicata Gould, 1837 Barn Owl
  Kiirodaia subpallidogaster (Piaget, 1880)
  Strigiphiliis aitkeni Clay, 1966

Order CAPRIMULGIFORMES
Family POD ARGIDAE
Genus Podargus Vieillot, 1818
  Podargus strigoides Latham, 1801 Tawny Frogmouth
  Podargoecus strigoides Emerson and Price, 1966
Family CAPRIMULGIDAE
Genus *Eurostopodus* Gould, 1838
*Eurostopodus argus* Hartert, 1892 Spotted Nightjar

*Multioca* sp.

Family AEGOTHELIDAE
Genus *Aegotheles* Vigors and Horsfield, 1826
*Aegotheles cristatus* (Shaw, 1790) Australian Owlet-nightjar

ORDER CORACIIFORMES
Family HALCYONIDAE
Genus *Dacelo* Leach, 1815
*Dacelo novaeguineae* (Hermann, 1783) Laughing Kookaburra

*Alcedo* sp.
*Emersonia* sp.

Genus *Todiramphus* Lesson, 1827
*Todiramphus sanctus* (Vigors and Horsfield, 1827) Sacred Kingfisher

*Alcedo* sp.

Family MEROPIDAE
Genus *Merops* Linnaeus, 1758
*Merops ornatus* Latham, 1801 Rainbow Bee-eater

*Meropon* sp.
*Merops* sp.

Family DICRURIDAE
Genus *Rhipidura* Vigors and Horsfield, 1827
*Rhipidura leucophrys* (Latham, 1801) Willie Wagtail

*Myrsidea* sp.

Family PARDALOTIDAE
Genus *Gerygone* Gould, 1841
*Gerygone fusca* (Gould, 1838) Western Gerygone

*Richms* sp.

Family MELIPHAGIDAE
Genus *Anthocephala* Vigors and Horsfield, 1827
*Anthocephala carunculata* (Shaw, 1790) Red Wattlebird

*Brueelia* sp.
*Menacanthus* sp.

Genus *Manorina* Vieillot, 1818
*Manorina flavigula* (Gould, 1840) Yellow-throated Miner

*Brueelia* sp.
*Philopterus* sp.

Genus *Lichenostomus* Cabanis, 1851
*Lichenostomus ornatus* (Gould, 1838) Yellow-plumed Honeyeater

*Brueelia* sp.
*Philopterus* sp.

ORDER PASSERIFORMES
Family MALURIDAE
Genus *Malurus* Vieillot, 1816
*Malurus splendens splendens* (Quoy and Gaimard, 1830) Splendid Fairy-wren

*Myrsidea* sp.
*Philopterus* sp.

Family PARDALOTIDAE
Genus *Coracina* Vieillot, 1816
*Coracina novachollandiae* (Gmelin, 1789) Black-faced Cuckoo-shrike

*Brueelia* sp.
Lice from Australian birds

Family ARTAMIDAE
Genus Gymnorhina Gray, 1840
Gymnorhina tibicen dorsalis (Campbell, 1895)
Australian Magpie
Brueelia semiannullata (Piaget, 1883)
Myrsidea sp.
Philopterus sp.
Gymnorhina tibicen hypoleuca (Gould, 1837)
White-backed Magpie
Brueelia semiannullata (Piaget, 1883)

Genus Gymnorhina Gray, 1840
Gymnorhina tibicen dorsalis (Campbell, 1895)
Australian Magpie
Brueelia semiannullata (Piaget, 1883)
Myrsidea sp.
Philopterus sp.

Family CINCLORAMPHALIDAE
Genus Cincloramphus Gould, 1838
Cincloramphus ruralis (Vigors and Horsfield, 1827)
Brown Songlark
Brueelia sp.

Family MOTACILLIDAE
Genus Anthus Bechstein, 1807
Anthus novaeseelandiae (Gmelin, 1789)
Richard’s Pipit
Menacanthus pusillus (Nitzsch, 1866)
Penenirniiis sp.
Philopterus sp.

Family SYLVIIDAE
Genus Gymnorhina Gray, 1840
Gymnorhina tibicen dorsalis (Campbell, 1895)
Australian Magpie
Brueelia semiannullata (Piaget, 1883)
Myrsidea sp.
Philopterus sp.

DISCUSSION
While discussing the imbalance between the recorded louse fauna of New Zealand and that of Australia, Murray et al. (1990: 1365) stated that “the apparent cleanliness of Aust. birds simply indicates an appalling lack of data”. The relative large number of louse records given here at the generic level is yet another indication of the need to further collect and study the Australian bird lice. Although some bird groups such as the Procellariiformes and the Pelecaniformes have been more extensively searched for lice, other large orders (e.g. Passeriformes and Columbiformes) have barely been investigated. The large number of Australian birds missing in the list of ‘Host-lice associations’ given by Palma and Barker (1996: 338) ensures that anyone who sets about collecting lice will no doubt add to the present knowledge.

This paper records 141 species and subspecies of bird lice and a further 59 records which are listed at the generic level only, but the latter do not necessarily represent different species. Among them, several species and subspecies were described based on the material collected by the senior author. They are: Anthostragioniodes metoeus, Franciscolora magnifici, Heteromenopon kalamundae, Myrsidea australiensis bennetti, Myrsidea strangeri, Physconelloides strangeri, Quadraseps bicuspis dressleri, Saemundssonia minutissima and S. tringae sibiriae. Also, several records represent new host-louse associations.

Two of the lice mentioned above are good examples of secondary infestations or host-switching (see Palma and Barker, 1996: 82).
*Aiistrogoniodes metaeocus* is a regular parasite of the Musk Duck, but all the remaining species of the genus *Aiistrogoniodes* are parasitic on penguins. Similarly, *Saemundssonia minutissima* is the only species of the genus *Saemundssonia* known to live on a duck, the Pink-eared Duck, while most of the many other *Saemundssonia* species are parasitic on members of the avian orders Charadriiformes and Procellariiformes.

**ACKNOWLEDGEMENTS**

We are indebted to Dr C. Lyal, Mr C. Moreby and the late Dr T. Clay for the identification of many of the lice listed here; to Ms C. Nicholls and Mr P. de Rubiera for providing suitable hosts and to Mr R. Johnstone for his assistance with bird nomenclature. Also, R.H.S. is very grateful to the late Drs D. Serventy and T. Spence for fostering his interest in feather lice.

**REFERENCES**


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Ctenotus rimacola sp. nov. (Scincidae), a new species of lizard with two allopatric subspecies, from the Ord-Victoria region of northwestern Australia

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and
Northern Territory University, Darwin, NT 0909, Australia

Abstract - A new species of Ctenotus Storr (Reptilia, Scincidae) with two allopatric subspecies, C. rimacola rimacola ssp. nov. and C. rimacola camptris ssp. nov., is described. A member of the C. lesueurii species-group, it is distinguished from congeners, notably C. robustus, C. joanae and C. agrestis, by a combination of body pattern and meristic characteristics. Two subspecies are recognised from geographic variation in colour and pattern within the taxon. This species is apparently endemic to areas of tussock grassland on black-soil (grey cracking clay) plains, which occur extensively in the Ord-Victoria region of northwestern Australia. Unlike the deserts of central Australian and the tropical savanna woodlands, black-soil grasslands in northern Australia support few Ctenotus species, although at least four species are endemic to this habitat.

INTRODUCTION

The genus Ctenotus Storr 1964 is the most speciose taxon of scincid lizard found in Australia. Containing more than 90 species (Wilson and Couper 1995), the genus is distributed throughout the continent, with one species occurring in southern New Guinea. Ctenotus species are found through a diverse array of habitats, ranging from arid deserts to tropical savanna woodland. Many species exhibit a high degree of habitat specificity and may have very restricted distributions (Horner 1995).

Mitchell Grass (Astrebla spp.) associations occur on heavy cracking-clay (black-soil) plains over a large area (c. 400 000 km²) of inland northern Australia. Reptile species endemic to this habitat include several elapid snakes [Pseudelphis colletti Boulenger 1902, Pseudonaja guttata (Parker 1926), P. ingrami (Boulenger 1908)], one varanid (Varanus spenceri Lucas and Frost 1903), one agamid (Pogona henrylawsoni Wells and Wellington 1985) and four skinks [Proablepharus kinghorni (Copland 1947), Ctenotus agrestis Wilson and Couper 1995, C. joanae Storr 1970 and C. schevilli (Loveridge 1933)]. During a study on fauna associated with Mitchell Grass communities, one of us (AF) collected a series of specimens of an unusual Ctenotus from black-soil habitats in the southern Victoria River District of the Northern Territory (Figure 1). These were recognised as being conspecific with a single damaged specimen collected by J. Woinarski from similar habitat on Victoria River Downs Station in 1994 (Woinarski and Fisher, unpubl. data). Further specimens, differing somewhat in colour and pattern to those from the Victoria River District, were collected by staff of Ecologia Environmental Consultants, Perth, WA, during the course of a biological survey of the alluvial black soil plains of the proposed Ord River Irrigation Area Stage II development (Figure 1).

The specimens share many features with C. robustus Storr 1970 and would be referred to that species by most identification keys. Additionally, the grey-brown ground colour and broad, dark vertebral stripe of the Victoria River District series, begs comparison to C. agrestis and C. joanae.

This paper describes the new species and its subspecies. A comparison is made with those species with which it could be confused and its known distribution and some features of its habitat are described.

METHODS

A detailed morphometric and meristic analysis was made of the 22 specimens available of the previously undescribed species of Ctenotus, 11 from each of the Victoria River District and Ord regions. The characters quantified for each specimen are listed in Table I. Measurements were made with
Figure 1 (a) Distribution of Clonius rimacola sp. nov. (C. r. rimacola — closed circles; C. r. camptris — open circles) and location of comparative specimens of C. robustus (triangles), C. panae (diamonds) and C. agaristis (cross). Stippling shows the distribution of Mitchell grass communities in northern Australia. (b) Detail of the collection localities of C. rimacola sp. nov. (C. r. rimacola — closed circles; C. r. camptris — open circles; type localities — stars), showing the distribution of heavy clay soils (stippled) in the region.
A new species of lizard from the Ord-Victoria region

electronic digital calipers and a steel rule. Counts of supraciliary, ciliary, and supralabial scales, subdigital lamellae and ear lobules were made on both sides of the body. The colouration and body pattern of each specimen was also recorded. Nomenclature for scation and body pattern follows that of Homer (1992). Of the measurements and counts taken, the following require individual definition:

1. Head length: measured from the anterior margin of the ear orifice to the apex of the rostral scale;
2. Snout length: measured from the anterior margin of the orbit to the apex of the rostral scale;
3. Body length: measured between axilla and groin;
4. Forebody length: measured from the tip of the snout to the axilla;
5. Limb length: measured along the posterior edge, from the body wall to the tip of the longest toe (claw excluded);
6. Paravertebral scales: counted from first scale posterior to parietals to a point midway between the hindlimbs.

For analytical purposes all measurements of a specimen were expressed as a proportion of the snout-vent length of that specimen in order to minimise variation due to body size. A further nine variables were derived as ratios between various combinations of body measurements (Table 1).

A similar set of characters were quantified for 28 specimens of C. robustus from a broad geographic range, 19 specimens of C. joanae from the Barkly Tableland within the Northern Territory and two paratypes of C. agrestis from central Queensland (Figure 1; Appendix 1). Mensural and meristic

Table 1  Mensural and meristic variables for Ctenotus r. rimacola ssp. nov. and C. r. camptris ssp. nov. Probability associated with Mann-Whitney U-test or χ² test between subspecies is given for each variable: 'ns' indicates P>0.1.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Ctenotus rimacola rimacola mean</th>
<th>Ctenotus rimacola camptris mean</th>
<th>n=22</th>
<th>range</th>
<th>n=22</th>
<th>range</th>
<th>prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of nuchal scales</td>
<td>6.8 (0.8)</td>
<td>6.0 - 8.0</td>
<td>n=11</td>
<td>6.7 (0.7)</td>
<td>6.0 - 8.0</td>
<td>n=22</td>
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<tr>
<td>No. of supraciliary scales (n=22)</td>
<td>10.0 (1.0)</td>
<td>9.0 - 13.0</td>
<td></td>
<td>9.4 (0.6)</td>
<td>9.0 - 11.0</td>
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<tr>
<td>No. of ciliary scales</td>
<td>11.3 (0.7)</td>
<td>10.0 - 13.0</td>
<td></td>
<td>11.0 (0.5)</td>
<td>10.0 - 12.0</td>
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<td>No. of nuchal scales</td>
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<td>6.7 (0.7)</td>
<td>6.0 - 8.0</td>
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<td>No. of ear lobules (n=22)</td>
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<td>11.0 - 14.0</td>
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<td>13.0 (1.0)</td>
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<td>No. of hindfoot lamellae (n=22)</td>
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<td>17.0 - 22.0</td>
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<td>19.4 (1.7)</td>
<td>17.0 - 22.0</td>
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<td>No. of midbody scale rows</td>
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<td>26.0 - 30.0</td>
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<td>27.8 (0.6)</td>
<td>26.0 - 28.0</td>
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<td>No. of paravertebral scales</td>
<td>55.0 (1.5)</td>
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<td>55.4 (1.6)</td>
<td>53.0 - 58.0</td>
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<tr>
<td>Nasals (% in contact)</td>
<td>63.6</td>
<td></td>
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<td>27.3</td>
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<td>Prefrontals (% in contact)</td>
<td>90.9</td>
<td></td>
<td></td>
<td>81.8</td>
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<td>Presubocular present (%) (n=22)</td>
<td>54.5</td>
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<tr>
<td>Snout-vent length (SVL)</td>
<td>78.6 (10.83)</td>
<td>59.0 - 94.0</td>
<td></td>
<td>81.4 (5.1)</td>
<td>72.0 - 88.0</td>
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</table>

Percentages (of SVL)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Ctenotus rimacola rimacola mean</th>
<th>Ctenotus rimacola camptris mean</th>
<th>n=22</th>
<th>range</th>
<th>n=22</th>
<th>range</th>
<th>prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body length</td>
<td>53.9 (3.4)</td>
<td>48.2 - 60.1</td>
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<td>49.9 (2.4)</td>
<td>47.3 - 54.2</td>
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<td>Tail length</td>
<td>181.0 (14.2)</td>
<td>166.7 - 199.1</td>
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<td>194.3 (7.4)</td>
<td>188.0 - 206.0</td>
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<td>Forelimb length</td>
<td>28.3 (1.8)</td>
<td>26.1 - 31.4</td>
<td></td>
<td>27.6 (1.5)</td>
<td>25.6 - 29.9</td>
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<td>Hindlimb length</td>
<td>41.6 (2.6)</td>
<td>38.1 - 46.3</td>
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<td>42.0 (1.9)</td>
<td>38.5 - 46.1</td>
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<tr>
<td>Forebody length</td>
<td>37.5 (2.8)</td>
<td>34.7 - 42.1</td>
<td></td>
<td>38.7 (1.4)</td>
<td>36.5 - 40.8</td>
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</tr>
<tr>
<td>Head length</td>
<td>18.7 (1.0)</td>
<td>17.2 - 20.3</td>
<td></td>
<td>19.1 (0.7)</td>
<td>17.8 - 20.2</td>
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<tr>
<td>Head width</td>
<td>13.1 (0.7)</td>
<td>11.9 - 14.2</td>
<td></td>
<td>13.2 (0.5)</td>
<td>12.5 - 14.1</td>
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<tr>
<td>Head height</td>
<td>10.6 (0.9)</td>
<td>9.3 - 12.2</td>
<td></td>
<td>11.1 (0.7)</td>
<td>10.3 - 12.6</td>
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</tr>
<tr>
<td>Snout length</td>
<td>8.2 (0.4)</td>
<td>7.6 - 8.7</td>
<td></td>
<td>8.3 (0.4)</td>
<td>7.6 - 8.9</td>
<td></td>
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</table>

Ratios

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Ctenotus rimacola rimacola mean</th>
<th>Ctenotus rimacola camptris mean</th>
<th>n=22</th>
<th>range</th>
<th>n=22</th>
<th>range</th>
<th>prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hindlimb : forelimb</td>
<td>1.47 (0.05)</td>
<td>1.37 - 1.58</td>
<td></td>
<td>1.52 (0.05)</td>
<td>1.43 - 1.50</td>
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<td>.04</td>
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<tr>
<td>Hindlimb : head length</td>
<td>2.22 (0.09)</td>
<td>2.07 - 2.35</td>
<td></td>
<td>2.20 (0.07)</td>
<td>2.09 - 2.32</td>
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</tr>
<tr>
<td>Forebody : forelimb</td>
<td>1.33 (0.09)</td>
<td>1.16 - 1.52</td>
<td></td>
<td>1.41 (0.09)</td>
<td>1.26 - 1.52</td>
<td></td>
<td>.07</td>
</tr>
<tr>
<td>Body : forebody</td>
<td>1.45 (0.18)</td>
<td>1.14 - 1.75</td>
<td></td>
<td>1.30 (0.09)</td>
<td>1.18 - 1.48</td>
<td></td>
<td>.04</td>
</tr>
<tr>
<td>Body : hindlimb</td>
<td>1.30 (0.14)</td>
<td>1.11 - 1.58</td>
<td></td>
<td>1.19 (0.07)</td>
<td>1.12 - 1.32</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Body : head length</td>
<td>2.89 (0.31)</td>
<td>2.47 - 3.43</td>
<td></td>
<td>2.62 (0.18)</td>
<td>2.45 - 3.04</td>
<td></td>
<td>.05</td>
</tr>
<tr>
<td>Body : snout length</td>
<td>6.60 (0.64)</td>
<td>5.53 - 7.40</td>
<td></td>
<td>6.04 (0.46)</td>
<td>5.58 - 7.08</td>
<td></td>
<td>.04</td>
</tr>
<tr>
<td>Head length: head height</td>
<td>1.77 (0.11)</td>
<td>1.59 - 1.95</td>
<td></td>
<td>1.72 (0.07)</td>
<td>1.60 - 1.85</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Head width : head height</td>
<td>1.24 (0.08)</td>
<td>1.11 - 1.37</td>
<td></td>
<td>1.19 (0.08)</td>
<td>1.00 - 1.30</td>
<td></td>
<td>ns</td>
</tr>
</tbody>
</table>
values for the holotype of *C. agrestis* were taken from Wilson and Couper (1995).

The mean, standard deviation and range of each variable were calculated for each taxon (Table 2). The following comparisons between taxa were made for each variable using Mann-Whitney U-tests, or $x^2$ tests for frequency data:

between Victoria River District and Ord region specimens of the new species;
between male and female specimens of the new species;
between all specimens of the new species and *C. robustus*, *C. joanae* and *C. agrestis*.

The similarity between all specimens in the latter comparison was also portrayed by ordination (semi-strong hybrid multidimensional scaling, Belbin 1994), using the variables measured for all specimens (Table 2). Variables showing a high degree of correlation ($r$>0.9) with another variable were not included. In order to remove the overwhelming influence of body size on the ordination, snout-vent length (SVL) was excluded and body measurements expressed as a percentage of SVL.

The following abbreviations are used in the text: NTM, Museum and Art Gallery of the Northern Territory; WAM, Western Australian Museum; NMV, Museum of Victoria; AM, Australian Museum; QM, Queensland Museum.

**RESULTS**

Meristic and mensural characters for specimens from the Victoria River District and Ord River region are shown in Table 1.

While there are significant differences ($P<0.05$) between specimens from the two regions for five of the measured variables in Table 1 [mean body

### Table 2

<table>
<thead>
<tr>
<th>Characteristics</th>
<th><em>C. rinchula</em> sp. nov.</th>
<th><em>C. robustus</em></th>
<th><em>C. joanae</em></th>
<th><em>C. agrestis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of nuchal scales</td>
<td>6.8 ± 0.7 (6-8)</td>
<td>7.4 ± 1.1 (4-9)</td>
<td>8.2 ± 0.7 (7-10)</td>
<td>8.0 ± 1.0 (7-9)</td>
</tr>
<tr>
<td>No. of supraciliary scales</td>
<td>9.7 ± 0.8 (9-13)</td>
<td>10.3 ± 1.0 (8-13)</td>
<td>7.7 ± 0.5 (7-9)</td>
<td>8.3 ± 0.6 (8-9)</td>
</tr>
<tr>
<td>No. of ciliary scales</td>
<td>11.2 ± 0.6 (10-13)</td>
<td>11.1 ± 0.5 (10-12)</td>
<td>10.6 ± 0.5 (10-11)</td>
<td>12.5 ± 0.7 (12-13)</td>
</tr>
<tr>
<td>No. of supralabial scales</td>
<td>7.2 ± 0.4 (7-8)</td>
<td>7.3 ± 0.4 (7-8)</td>
<td>7.1 ± 0.3 (7-8)</td>
<td>7.5 ± 0.0 (7-8)</td>
</tr>
<tr>
<td>No. of ear lobules</td>
<td>3.2 ± 0.4 (2-4)</td>
<td>4.4 ± 0.6 (3-6)</td>
<td>2.7 ± 0.4 (2-3)</td>
<td>3.2 ± 0.3 (3-4)</td>
</tr>
<tr>
<td>No. of hindfoot lamellae</td>
<td>19.5 ± 1.6 (17-22)</td>
<td>21.2 ± 1.1 (18-24)</td>
<td>19.3 ± 1.5 (17-22)</td>
<td>17.8 ± 1.0 (17-19)</td>
</tr>
<tr>
<td>No. of midbody scale rows</td>
<td>28.0 ± 0.8 (26-30)</td>
<td>29.7 ± 1.3 (26-32)</td>
<td>26.2 ± 0.7 (25-28)</td>
<td>30 ± 0.1 **</td>
</tr>
<tr>
<td>No. of paravertebral scales</td>
<td>55.2 ± 1.5 (52-58)</td>
<td>64.5 ± 3.3 (58-64)</td>
<td>54.6 ± 2.3 (51-59)</td>
<td>61.3 ± 1.5 (60-63) **</td>
</tr>
<tr>
<td>Nasals (% in contact)</td>
<td>45.5</td>
<td>51.8</td>
<td>100 ***</td>
<td>100^</td>
</tr>
<tr>
<td>Prefrontals (% in contact)</td>
<td>86.4</td>
<td>100</td>
<td>0 **</td>
<td>0 *</td>
</tr>
<tr>
<td>Presubocular present (%)</td>
<td>77.3</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Snout-vent length (SVL)</td>
<td>80.0 ± 8.4 (59-94)</td>
<td>100 ± 17.1 (60-125)</td>
<td>70.8 ± 9.9 (55-86)</td>
<td>72.8 ± 3.5 (69-76)</td>
</tr>
</tbody>
</table>

**Percentages of (SVL)**

| Body length | 51.9 ± 3.5 (47.3–60.1) | 54.0 ± 3.2 (46.3–60.5) | 54.2 ± 3.8 (46.9–62.1) | 52.2 ± 2.9 (49.2–55.1) |
| Tail length | 187.0 ± 12.8 (167–206) | 192.3 ± 30.0 (171–213) | 192.6 ± 13.6 (169–196) | 162 ± 9.1 (156–168) |
| Forelimb length | 27.9 ± 1.7 (25.6–31.4) | 23.6 ± 2.0 (20.9–28.1) | 26.8 ± 2.0 (21.4–31.5) | 26.2 ± 1.4 (24.8–27.7) |
| Hindlimb length | 41.8 ± 2.2 (38.1–46.3) | 40.0 ± 2.8 (33.8–46.0) | 41.8 ± 4.2 (33.0–49.3) | 38.7 ± 1.1 (37.5–39.4) |
| Forebody length | 38.1 ± 2.2 (34.7–42.1) | 38.0 ± 3.0 (33.5–40.8) | 36.4 ± 2.1 (33.1–41.3) | 34.9 ± 1.7 (33.1–36.5) |
| Head length | 18.9 ± 0.8 (17.2–20.3) | 18.8 ± 1.3 (17.1–21.1) | 18.5 ± 1.5 (16.0–21.6) | 19.1 ± 0.3 (18.9–19.3) |
| Head width | 13.1 ± 0.6 (11.9–14.2) | 12.4 ± 1.0 (10.7–14.4) | 12.8 ± 1.0 (11.2–15.1) | 13.0 ± 0.4 (12.9–13.1) |
| Head height | 10.9 ± 0.8 (9.3–12.6) | 10.8 ± 0.9 (9.5–13.1) | 10.2 ± 1.1 (8.3–12.7) | 10.8 ± 0.3 (10.6–11.1) |
| Snout length | 8.2 ± 0.4 (7.6–8.9) | 8.2 ± 0.8 (6.9–10.1) | 8.8 ± 0.9 (7.4–9.9) | 7.9 ± 0.5 (7.4–8.3) |

**Ratios**

| Hindlimb: forelimb | 1.50 ± 0.1 (1.37–1.61) | 1.69 ± 0.1 (1.49–1.90) | 1.56 ± 0.1 (1.35–1.69) | 1.48 ± 0.1 (1.43–1.51) |
| Forelimb: head length | 2.21 ± 0.1 (2.07–2.35) | 2.13 ± 0.1 (1.95–2.39) | 2.26 ± 0.2 (1.74–2.47) | 2.26 ± 0.2 (1.74–2.47) |
| Forebody: forebody | 1.37 ± 0.1 (1.16–1.52) | 1.47 ± 0.1 (1.40–1.54) | 1.36 ± 0.1 (1.25–1.55) | 1.33 ± 0.1 (1.27–1.39) |
| Body: forebody | 1.37 ± 0.2 (1.14–1.72) | 1.42 ± 0.2 (1.26–1.68) | 1.51 ± 0.2 (1.13–1.84) | 1.50 ± 0.1 (1.43–1.57) |
| Body: hindlimb | 1.25 ± 0.1 (1.11–1.58) | 1.36 ± 0.2 (1.06–1.66) | 1.31 ± 0.2 (1.02–1.57) | 1.35 ± 0.1 (1.31–1.40) |
| Body: head length | 2.76 ± 0.3 (2.24–3.43) | 2.90 ± 0.3 (2.29–3.55) | 2.96 ± 0.4 (2.26–3.67) | 2.81 ± 0.1 (2.77–2.85) |
| Body: snout length | 6.32 ± 0.6 (5.53–7.40) | 6.66 ± 0.9 (5.12–8.44) | 6.23 ± 1.0 (4.91–8.17) | 6.59 ± 0.2 (5.36–6.72) |
| Head length: head height | 1.75 ± 0.1 (1.59–1.95) | 1.74 ± 0.1 (1.55–2.05) | 1.82 ± 0.1 (1.52–2.18) | 1.77 ± 0.1 (1.71–1.83) |
| Head width: head height | 1.22 ± 0.1 (1.10–1.37) | 1.15 ± 0.1 (1.06–1.30) | 1.26 ± 0.1 (1.06–1.55) | 1.20 ± 0.1 (1.18–1.22) |
A new species of lizard from the Ord-Victoria region

length (% of SVL); mean ratio of forelimb to hindlimb length; mean ratio of forebody to body length; mean ratio of head to body length; mean ratio of snout to body length], the ranges of each variable have considerable overlap.

Tests of sexual dimorphism revealed that males of C. r. rimacola ssp. nov. and C. r. camptris ssp. nov. have significantly shorter bodies and forebodies than do females. Additionally, male C. r. rimacola ssp. nov. have significantly wider heads and longer forelimbs than do females. To determine if this sexual dimorphism contributed to observed differences in body proportions between populations, those five variables which indicate significant differences were tested between populations for each sex separately. The results showed that body proportions do not differ significantly between males of the two populations, while females differed significantly only in the ratio of forelimb length to hindlimb length (C. r. rimacola ssp. nov.: mean = 1.46, sd = 0.06, n = 8; C. r. camptris ssp. nov.: mean = 1.57, sd = 0.04, n = 3; P = 0.024).

Greater differences between specimens from the two areas are found in body colour and pattern. The Ord population have an olive-brown ground colour (rather than grey-brown in Victoria River District populations), a noticeably narrower dark vertebral stripe (three quarters as wide as paravertebral scales) and absent to obscure dark laterodorsal and pale dorsolateral stripes vs distinct stripes. In colour and pattern, Victoria River District specimens more closely resemble C. joanae while Ord specimens are more similar to C. robustus.

Differences between the Victoria River District and Ord populations are not considered sufficient to warrant their description as separate species as they cannot be reliably diagnosed on any single character or combination of characters. The populations are therefore assigned to subspecies, but exact relationships cannot be resolved until further specimens of each population and from the intervening area become available. However, differences between the new taxa and other Ctenotus species are consistent for both type series.

SYSTEMATICS

Ctenotus rimacola rimacola ssp. nov.

Figures 2, 3, 4

Material Examined

Holotype

NTM R.22905, adult male, Lindermans Bore, Limbunya Station, 17°33'S 130°05'E, Northern Territory, Australia, collected by A. Fisher, 06 October 1996.

Paratypes


Diagnosis

A moderately large and robust member of the C. lesueurii species-group, C. r. rimacola ssp. nov. differs from other members of this species-group by having prefrontals usually in contact, seven supralabials, prominent pale dorsolateral stripe, distinct dark, pale edged vertebral stripe and a maximum snout-vent length of 94 mm. It is distinguished from C. r. camptris ssp. nov. in having a grey-brown ground colour and more intense patterning, with a prominent dark vertebral stripe as wide as paravertebral scales, distinct dark laterodorsal and pale dorsolateral stripes and longitudinally striped pattern on hindlimbs.

Description

Head

Snout length 41–46% (mean = 43.8%) of head length. Prefrontal scales usually in broad contact (90.9%). Nasal scales usually in narrow contact (63.6%), or narrowly separated by rostral and frontonasal scales. Frontoparietal scales paired. Interparietal scale distinct. Loreal scales two, second larger than first. Upper and lower preocular scales present. Presubocular scale present (54.5%) or absent (45.5%), being fused with subocular scale. Nuchal scales six to eight (mean = 6.8). Supraciliary scales nine to thirteen (mean = 10.0), median five or six much smaller than first three and final scale in series. Ciliary scales ten to thirteen (mean = 11.3). Supralabial scales seven or eight (mean = 7.4), fifth or sixth under orbit. Ear lobules three or four (mean = 3.3).

Body

Snout-vent length to 94 mm (mean = 78.6 mm). Body length 48–60% (mean = 53.9%) of snout-vent length. Tail length 167–199% (mean = 181%) of snout-vent length. Paravertebral scales 52–57 (mean = 55). Midbody scale rows 26–30 (mean = 28.1)

Limbs

Forelimb length 26–31% (mean = 28.3%) of snout-vent length. Hindlimb length 38–46% (mean =
41.6%) of snout-vent length. Subdigital lamellae under fourth toe 17–22 (mean = 19.5).

Colour and pattern (in spirit)

Holotype

Body pattern consists of a complex arrangement of smooth-edged, longitudinal stripes, zones of ground colour and pale blotches (Figure 2).

Body

Dorsal surface pale grey-brown, patterned with smooth-edged stripes. Prominent, broad, blackish-brown vertebral stripe, as wide as paravertebral scales, extends from anterior nuchal scales to base of tail. Vertebral stripe margined by obscure, white paravertebral stripes which are about one quarter as wide as vertebral stripe. Paravertebral stripes bordered by zones of grey-brown background colour, about as wide as paravertebral scales, which extend from parietal scales onto tail. Outer margins of background colour zones bordered by prominent, blackish-brown laterodorsal stripes, about half as wide as vertebral stripe, which extend from outer edge of parietal scales onto tail. Outer margins of laterodorsal stripes bordered by distinct, white dorsolateral stripes, about a third as wide as vertebral stripe, which extend from outer edge of fourth supraciliary scales onto tail. Lateral surface of body light grey-brown, patterned with pale blotches and pale mid-lateral stripe. Broad light grey-brown upper lateral zone extends from above auricular opening onto tail and is patterned with single, regular series of 19–20 large pale blotches. White mid-lateral stripe most prominent posteriorly, about one third as wide as upper lateral zone, extends from upper posterior margin of auricular opening, above limbs onto tail. Between midbody and auricular opening, mid-lateral stripe broken into series of elongate pale blotches. Grey lower lateral zone, about three quarters as wide as upper lateral zone, extends from below auricular opening to hindlimb, zone patterned by a series of about ten obscure pale blotches. Lower lateral zone coalesces into immaculate whitish ventral surface.

Head

Immaculate light brown dorsally. Temporal region brown, patterned with a single pale blotch. Obscure, white subocular stripe extends from first loreal scale to auricular opening. Supralabials pale grey. Infralabials off-white. Ventral surface white, changing to cream on mental scale.

Limb

Immaculate light brown ground colour on dorsal surface of forelimbs. Off-white on ventral surface. Hindlimbs similar but patterned with three or four obscure brown stripes.

Tail

Light grey-brown on dorsal surface. Basal portion has remnants of dark vertebral stripe. Laterally, continuations of dark laterodorsal stripes, pale dorsolateral stripes, upper lateral zone and pale mid-lateral stripes extend along anterior two thirds of tail. Off-white on ventral surface.

Variation in paratypes

Variation in meristic and mensural variables of
A new species of lizard from the Ord-Victoria region

Figure 3 Paratype of Ctenotus rimacola rimacola ssp. nov. (NTM R.22804), showing typical body pattern.

Paratypes are summarised in Table 1. Most specimens conform to the holotype’s body pattern and colour, differing only in intensity (Figure 3) (eg. vertebral and laterodorsal stripes black in 50% of specimens) and continuity of pale mid-lateral stripe (varies from continuous for length of body to a prominent longitudinal series of elongate blotches and dashes). Two specimens (NTM R.20444, NTM R.23242) have the pale dorsolateral stripes broken, on the anterior third of body, into a series of pale elongate dashes. Pattern and colour become increasingly drab as specimens age.

Sex ratio and sexual dimorphism
The sex ratio of the specimens examined favoured females (3:8). All meristic and mensural variables were tested for sexual dimorphism, with significant differences being found only for head width (% of SVL) (males: mean = 13.9, sd = 0.30, n = 3; females: mean = 12.8, sd = 0.64, n= 8; P = 0.014); ratio of forebody length to body length (males: mean = 1.28, sd = 0.15, n = 3; females: mean = 1.51, sd = 0.16, n= 8; P = 0.041); and, ratio of forelimb length to forebody length (males: mean = 1.43, sd = 0.09, n = 3; females: mean = 1.29, sd = 0.05, n= 8; P = 0.014). Mean body length (% of SVL) also differed between sexes, although probability was slightly greater than 0.05 (males: mean = 50.9, sd = 2.88, n = 3; females: mean = 55.0, sd = 3.01, n= 8; P = 0.066).

Details of holotype
(NTM R.22905). Adult male. Snout-vent length 82.5 mm; tail length 156 mm; body length 39.7 mm; forelimb length 22.8 mm; hindlimb length 33.3 mm; head width 11.7 mm; head depth 8.8 mm; snout length 7.2 mm; head length 16.1 mm; forelimb to snout length 34.7 mm; nasals in narrow contact; prefrontals in narrow contact; supraciliaries nine on both sides; ciliaries 12 on both sides; supralabials seven on both sides; nuchal scales eight; ear lobules four on both sides, second from top largest; subdigital lamellae under fourth toe 17 on both sides; midbody scale rows 27; paravertebral scales 55.

Heart and liver tissue samples were taken from the holotype at death. These are lodged in the South Australian Museum’s tissue bank under the number SAM-EBU Z99.

Etymology
The epithet rimacola is a combination of the Latin rima (cleft or fissure) and cola (dwelling in) and refers to the distinctive, deeply cracking clay soils which this species inhabits.

Distribution and conservation status
The known distribution of C. r. rimacola ssp. nov. is in the Victoria River District of the northwestern Northern Territory (Figure 1). In this region it has been collected on Mount Sanford, Kirkimbie, Victoria River Downs, Limbunya and Kidman Springs Stations.

Using the quantitative ranking method adopted by Cogger et al. (1993) to assess conservation status, and conservatively extrapolating some variables from congeners, C. r. rimacola ssp. nov. is scored at 22.3. This score is within the range assigned to the “Rare or insufficiently known” category.
Habitat
All specimens were collected from areas of grey to grey-brown heavy clay soil, which is fissured by deep cracks for the majority of the year. Collection locations from Kirkimbie and Limbunya Stations were on treeless plains, while those on Mount Sanford, Victoria River Downs and Kidman Springs were plains or gently undulating rises with sparse woodland of *Terminalia arartrata* and *T. volucris*. In most cases the understorey was dominated by perennial grasses to 40 cm tall, including *Astrebla pectinata*, *A. elymoides*, *A. squarrosa*, *Chrysopogon fallax*, *Dianthus secundum* and *Aristida latifolia*. At Victoria River Downs, the understorey was dominated by the annual grass *Brachyachne convergens* and the forbs *Sesbania simpliciuscula* and *Jacquemontia browniana*. At the time of collection, late in the Dry season, understorey cover ranged from 7% to 38%.

*Ctenotus rimacola camptris* ssp. nov.

Figures 5, 6

Material Examined

**Holotype**

WAM R.126064, adult male, c. 4 km south-west of Point Spring Yard, 15°25'S 128°51'E, Western Australia, Australia, collected by Ecologia Environmental Consultants, 14 October 1996.

**Paratypes**
A new species of lizard from the Ord-Victoria region


Diagnosis
A moderately large and robust member of the C. lesueurii species-group, C. r. campiris ssp. nov. differs from other members of this species-group by having prefrontals usually in contact, seven supralabials, prominent pale dorsolateral stripe, distinct dark, pale edged vertebral stripe and a maximum snout-vent length of 88 mm. It is distinguished from C. r. rimacoia ssp. nov. in having an olive-brown ground colour and less intense patterning, with a narrower dark vertebral stripe, obscure dark laterodorsal and pale dorsolateral stripes and dark mottling on hindlimbs.

Description

Head
Snout length 41–45% (mean = 43.5%) of head length. Prefrontals scales usually in broad contact (81.8%). Nasal scales usually narrowly separated (72.7%) by rostral and frontonasal scales, occasionally in narrow contact. Frontoparietal scales paired. Interparietal scale distinct. Loreal scales two, second larger than first. Upper and lower preocular scales present. Presubocular scale present. Nuchal scales six to eight (mean = 6.7). Supraciliary scales nine to eleven (mean = 9.4), median five or six much smaller than first three and final scale in series. Ciliary scales ten to twelve (mean = 11.0). Supralabial scales seven, fifth under orbit. Ear lobules two to four (mean = 3.0).

Body
Snout-vent length to 88 mm (mean = 81.4 mm). Body length 47–54% (mean = 49.9%) of snout-vent length. Tail length 188–206% (mean = 194%) of snout-vent length. Paravertebral scales 53–58 (mean = 55.4). Midbody scale rows 26–28 (mean = 27.8). Limbs
Forelimb length 25–30% (mean = 27.6%) of snout-vent length. Hindlimb length 38–46% (mean = 42%) of snout-vent length. Subdigital lamellae under fourth toe 17–22 (mean = 19.4).

Colour and pattern (in spirit)

Holotype
Body pattern consists of a complex arrangement of smooth-edged, longitudinal stripes, zones of ground colour and pale blotches (Figure 5).

Figure 5 Holotype of Ctenotus rimacola campiris ssp. nov. (WAM R.126064).
vertebral stripe, which extend from outer edge of parietal scales to hindlimb. Lateral surface of body olive-brown, patterned with pale blotches and pale mid-lateral stripe. Broad olive-brown upper lateral zone extends from above auricular opening to hindlimb and is patterned with single, regular series of 18–19 large pale blotches. White mid-lateral stripe most prominent posteriorly, about one third as wide as upper lateral zone, extends from midpoint between auricular opening and forelimb, above limbs onto tail. On anterior third of body, mid-lateral stripe broken into series of elongate pale streaks and blotches. Light brown lower lateral zone, about three quarters as wide as upper lateral zone, extends from below auricular opening to hindlimb, zone patterned by a series of about 10–12 obscure pale blotches. Lower lateral zone coalesces into immaculate whitish ventral surface.

Head

Limbs
Immaculate olive brown ground colour on dorsal surface of forelimbs. Off-white on ventral surface. Hindlimbs similar but obscurely patterned with brown flecks and variegations.

Tail
Olive-brown on dorsal surface. Basal portion has remnants of dark vertebral stripe. Laterally, vague discontinuous remnants of dark laterodorsal stripes, pale dorsolateral stripes, upper lateral zone and pale mid-lateral stripes extend along anterior two thirds of tail. Off-white on ventral surface.

Variation in paratypes
Variation in meristic and mensural variables of paratypes is summarised in Table 1. Most specimens conform to the holotype’s body pattern and colour, differing only in intensity of pattern (eg. narrow dark laterodorsal and pale dorsolateral stripes prominent and continuous to virtually absent) and continuity of pale mid-lateral stripe (varies from continuous for length of body to broken anteriorly into a series of elongate blotches and dashes).

Sex ratio and sexual dimorphism
The sex ratio of the specimens examined favoured males (8:3). All meristic and mensural variables were tested for sexual dimorphism, with significant differences found only for body length (% of SVL) (males: mean = 48.7, sd = 1.11, n = 8; females: mean = 53.3, sd = 1.45, n= 3; P = 0.014); and ratio of forebody to body length (males: mean = 1.25, sd = 0.05, n = 8; females: mean = 1.42, sd = 0.06, n= 3; P = 0.014).

Details of holotype
(WAM R.126064). Adult male. Snout-vent length 81.0 mm; tail length 155 mm; body length 39.5 mm; forelimb length 22.6 mm; hindlimb length 33.6 mm; head width 10.9 mm; head depth 8.95 mm; snout length 6.53 mm; head length 15.3 mm; forelimb to snout length 30.1 mm; nasals broadly separated; prefrontals in narrow contact; supraciliaries nine on both sides; ciliaries 11 on right, 12 on left; supralabials seven on both sides; nuchal scales six; ear lobules three on left, four on right, upper largest; subdigital lamellae under fourth toe 21 on both sides; midbody scale rows 28; paravertebral scales 55.

Etymology
The epithet rimacola is a combination of the Latin rima (cleft or fissure) and cola (dwelling in) and refers to the distinctive, deeply cracking clay soils which this species inhabits. Camptris is derived from the Latin campus (field or plain) and -iris (where or place for) and also refers to the black-soil plains which this subspecies inhabits.

Distribution and conservation status
The known distribution of C. r. camptris ssp. nov. is on the northern floodplains of the Ord and Keep Rivers, adjacent to the Western Australia/Northern Territory border (Figure 1). In this region it has been collected north of Kununurra, near Mount Septimus and Point Spring Yard in Western Australia, and on Spirit Hills Station in the Northern Territory.

Using the quantitative ranking method adopted by Cogger et al. (1993) to assess conservation status, and conservatively extrapolating some variables from congeners, C. r. camptris ssp. nov. is scored at 22.3. This score is within the range assigned to the “Rare or insufficiently known” category.

Habitat
All specimens were collected from alluvial plains of grey or brown cracking clays. These habitats typically have an understorey of Chrysopogon, Dicauanthum, Themeda and Sorghum spp. and often a sparse overstorey of Lysiphyllum cunninghamii.

COMPARISON WITH SIMILAR SPECIES
As an aid to identification of Ctenotus in Western
A new species of lizard from the Ord-Victoria region

Australia, Storr (Storr 1981; Storr et al. 1981) distributed the species from that region among ten species-groups. Based on characters in common, these species-groups are not necessarily natural but are useful in clustering similar species together. Wilson and Knowles (1988) tentatively recognised twelve species-groups incorporating all *Clenotus* species. The following five character states in combination place the new taxa in the *C. le sueurii* species-group of Storr (Storr 1981; Storr et al. 1981).

Digits slightly compressed, smooth or with moderately broad, dark calli on the subdigital lamellae. Usually four supraocular scales, first three contacting frontal, second larger than first, third and fourth. Supraciliary scales very disparate in size (a median series much smaller than others). Ear lobules large and graded in size. Colour pattern includes a dark, pale-edged vertebral stripe.

Horner (1995) summarises the content of the *C. lesueurii* species-group as: *C. arcanus* Czechura and Wombey; *C. arthrogenensis* Storr; *C. astictus* Horner; *C. borealis* Horner and King; *C. brachyonyx* Storr; *C. capricorni* Storr; *C. coggeri* Sadlier; *C. cypripedium* Czechura and Wombey; *C. eulacus* Storr; *C. fallens* Storr; *C. helenae* Storr; *C. hypatia* Ingram and Czechura; *C. ingrami* Czechura and Wombey; *C. hornatus* (Gray); *C. lateralis* Storr; *C. lesueurii* (Duméril and Bibron); *C. mastigura* Storr; *C. monticola* Storr; *C. nullus* Ingram and Czechura; *C. robustus* Storr; *C. saxatilis* Storr; *C. severus* Storr; *C. spaldingii* (Macleay); *C. stuarti* Horner; *C. taeniolatus* (White, ex Shaw); *C. terrareginae* Ingram and Czechura; and *C. vertebralis* Rankin and Gillam. To these can now be added *C. agrestis* Wilson and Couper and *C. rimacola*. Additionally, based on its narrowly callused subdigital lamellae, *C. joaiae* is considered by Storr (1970) to be an aberrant member of the *C. leonhardii* species-group. However, it could equally be considered a member of the *C. lesueurii* species-group, as it agrees in most other respects with the criteria for that group.

The new taxa is distinguished from other members of the *C. lesueurii* species-group by the following eight character states in combination: four supraocular scales; body dorsal surface with

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**Figure 6** Holotype of *Clenotus rimacola camptris* ssp. nov. (WAM R.126064). Head scalation in a) dorsal and b) right lateral view. Scale bar = 5 mm
dorsolateral stripes present; maximum snout-vent scales; pale subocular stripe present; white dorsolateral stripes present; maximum snout-vent length less than 100 mm; paravertebral scales less than 59.

Those species with which C. rimacola could be confused are C. robustus, C. joanae and C. agrestis. Table 2 summarises mensural and meristic variables of the four species.

Ctenotus rimacola can be distinguished from C. robustus by having fewer paravertebral scales (mean = 55.2 [range 52–58] vs 64.5 [58–69]). Although the ranges overlap for other variables, C. rimacola also has significantly fewer midbody scale rows (mean 27.9 vs 29.7), fewer ear lobules (mean 3.2 vs 4.4), fewer hindfoot lamellae (mean 19.5 vs 21.2), shorter hindlimbs (relative to body length), and narrower relative headwidth. Ctenotus rimacola also has a smaller recorded maximum size than C. robustus (SVL 94 vs 125 mm).

Ctenotus rimacola can usually be distinguished from C. joanae by having prefrontal scales in contact rather than separated. While ranges of the variables overlap, C. rimacola has significantly higher midbody scale count (mean = 55.2 [range 52–58] vs 64.5 [58–69]). Although measurements for only three specimens of C. agrestis are available, C. rimacola can be distinguished from this species by usually having prefrontal scales in contact rather than separated, fewer paravertebral scales (52–58 vs 60–63) and less midbody scale rows (mean 27.9 vs 30).

The ordination of specimens of the four species by 23 measured characters is shown in Figure 7. While C. joanae and C. robustus are clearly separated, specimens of C. rimacola occupy an intermediate position in the ordination space.

**DISCUSSION**

The Ctenotus fauna of the arid centre and monsoonal north of Australia is diverse, with a high number of sympatric, or even syntopic, species in both deserts and savanna woodland (Pianka 1969, Reid et al. 1993, Sadlier et al. 1985, Horner 1995). By contrast, few Ctenotus species are found on black-soil plains in northern Australia, reflecting the low diversity of the reptile fauna generally, and presumably arising from the very limited habitat variability. Many of the common reptile species of black-soil plains do however show a strong fidelity to this habitat. Recent biological survey of the Barkly Tableland of the Northern Territory (Fisher, unpubl. data) showed that Ctenotus joanae was widespread, occurring at 61 of 77 black-soil sample sites, and was the most abundant reptile recorded. However, this species was absent from sites in red loam soils immediately adjacent to the black soil plains. Conversely, while a number of Ctenotus species were recorded from loam sites, no other Ctenotus species was recorded from black soil sites, with the exception of C. pulchellus Storr 1978 which occurred only on low gravelly rises and C. leonhardii (Sternfeld 1919), which occurred patchily on the southern margin of the clay plains. The extensive black soil grasslands of central Queensland appear to contain a greater diversity of Ctenotus species, with at least four taxa reported to occur in this environment (C. joanae, C. robustus, C. schlealli and C. agrestis; Wilson and Knowles 1988, Ingram and Raven 1991, Cogger 1994, Wilson and Couper 1995). However, the distribution of reptile species in this region is very poorly known and systematic survey is required to determine whether these species are geographically or environmentally partitioned.
Ctenotus rimacola appears to be the ecological analogue of C. joanae in the black-soil grasslands of northwestern Australia. The limited systematic sampling in this area to date indicates that C. r. rimacola is moderately common, occurring in 11 of 25 sample sites (Fisher unpubl. data). It was also the only Ctenotus species recorded from these sites, although Horner (1992) reports that C. militaris Storr 1975 (which is very similar to C. pulchellus) is found in black soil grasslands in this region. Ctenotus rimacola has not been recorded from habitats other than black-soil grasslands, while C. robustus and C. inornatus Gray 1845 were present at loam woodland sites immediately adjacent to black soil plains where C. rimacola occurred (G. Connell pers. comm., Fisher unpubl data). The black-soil plains of the Victoria River District are isolated from those of the Barkly Tableland by the lateritic surface of the Sturt Plateau, which separates them by a minimum distance of approximately 200km. This barrier represents the westerly limit of a number of other black-soil-endemic reptile species which are common on the Barkly Tableland, such as Varanus spenceri and Pseudonaja guttata.

We postulate that C. rimacola and C. joanae are closely related taxa, that have either speciated following the isolation of previously more contiguous black-soil environments in northern Australia, or are commonly derived from a broadly distributed ancestor (such as C. robustus). Ctenotus rimacola does not however appear to merely represent the extreme end of a geographical cline in C. joanae, as the ordering of specimens of C. joanae in the ordination space (Figure 7) shows no relationship with their geographic ordering.

As their exact affinities remain unresolved by detailed meristic and mensural analysis (Table 1), further work (eg. allozyme electrophoresis) is needed to clarify the status of the two subspecies attributed here to C. rimacola. Frozen tissues are available for C. r. camptris, but only the holotype of C. r. rimacola has been tissue sampled. The two populations are apparently allopatric and may be geographically isolated, as the inland plains of the Victoria River Downs are separated from the coastal Ord and Keep River plains by the dissected Victoria River Plateau. This is a region of rocky skeletal soils, although it does contain scattered patches of clay soils (Stewart et al 1970). It remains for further biological survey to determine whether the distribution of C. rimacola also extends into the black-soil grasslands in the western and southern Kimberley region of Western Australia.

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We are grateful to L. Smith of the Western Australian Museum for bringing the Ord River series of specimens to our attention, and for the loan of specimens in his care. Habitat details for the Ord River series were supplied by Ecologia Environmental Consultants. Comparative C. robustus material was loaned to us by John Coventry of the Museum of Victoria and by Ross Sadlier of the Australian Museum. Ctenotus aegrestis specimens were loaned by Patrick Couper of the Queensland Museum. Biological survey of Mitchell Grass communities in the Northern Territory was funded by the grants to the Parks and Wildlife Commission NT from the National Reserve System Program (Environment Australia) and the National Estate Grant Program (Australian Heritage Commission). Maps were prepared by Damian Milne. Helpful comments on the manuscript were provided by John Woinarski. Rick Bawden photographed specimens for figures 4 and 6.

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Ctenidae) in the Northern Territory. *Journal of the Royal Society of Western Australia* 52: 97–108


Appendix 1. Comparative specimens examined.

**Ctenotus agrestis**

*QUEENSLAND*: PARATYPES, QMJ.46689, QMJ.46695, 22°57'S 145°14'E, Brendallan Station.

**Ctenotus joanae**


*QUEENSLAND*: AM R.62271, AM R.62273, AM R.62275, 22°46'S 144°53'E, 38km S Muttaburra.

*WESTERN AUSTRALIA*: NTM R.13031, 16°15'S 128°45'E, Lake Argyle.

NTM R.23221, NTM R.23225, 16°54'S 133°19'E, Hayfield Stn; NTM R.23236, 21°11'S 137°09'E, Georgina Downs Stn; NTM R.32016 (CAMR484), 20°12'S 137°27'E, Alroy Downs Stn; NTM R.32017 (NTM5337), 18°57'S 136°05'E, Alroy Downs Stn; NTM R.32021 (NTM5365), 18°05'S 136°34'E, Connells Lagoon Conservation Reserve.

**Ctenotus robustus**


*QUEENSLAND*: AM R.62271, AM R.62273, AM R.62275, 22°46'S 144°53'E, 38km S Muttaburra.

*WESTERN AUSTRALIA*: NTM R.13031, 16°15'S 128°45'E, Lake Argyle.

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Arms of the South Australian volunteers in the Permanent Force artillery at Albany, Western Australia 1893–1901

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Abstract – A number of South Australian marked specimens of artillery pattern firearms and bayonets are examined and described. Evidence linking them to the South Australian volunteers who initially manned the Albany harbour defence artillery site in 1893 is discussed.

INTRODUCTION

The defence of the various colonies established on the continent of Australia by Britain initially lay with Imperial troops stationed in the various colonies by the British crown. In the late 1850's, Britain announced the planned withdrawal of her troops from Australia by the early 1860's and the colonists thus became aware that defence would be their own responsibility thereafter. This announcement led to the establishment of numbers of volunteer colonial infantry, artillery and cavalry corps throughout the Australian colonies by the mid 1860's. A Defence Report prepared in 1881 recommended a number of coastal defences be built around Australia to guard against attack or invasion by a foreign power. With the evolution towards self government in the colonies, the concept of a joint colonial defence scheme emerged and the colonies agreed, in 1887, to jointly fund the cost of establishing and maintaining the series of harbour and coastal defence sites around Australia. This joint scheme was in reality a foreshadowing of the Federal defence structure which was soon to be established when Australia became a Commonwealth of States in 1901. Western Australia's defence site was to be artillery batteries situated in fortifications on Mt Adelaide which commanded the approaches to Princess Royal harbour in the port of Albany (King George III Sound), and Point King which controlled the entrance to the harbour. Construction of the forts commenced in 1891.

In accordance with the joint defence agreement the task of recruiting and training men to man the guns was undertaken by South Australia who provided a fully trained crew of artillerymen who had volunteered from the ranks of their military for Western Australian service. South Australia already possessed up to date artillery and the means of training new crews. Two non-commissioned officers and 26 men were recruited in South Australia in 1892 and trained there at Fort Glanville before arriving in Albany on 28th February, 1893, under the command of Capt. J. C. Hawker and Sergeant-Major Hollingsworth.

The regulations pertaining to the establishment of a Permanent Force of artillerymen, (and engineers), was announced in the Western Australian Government Gazette of 6th April, 1893.

The regulations prescribed that the corps were to be known as the Western Australian Artillery (WAA), of the Western Australian Permanent Force (WAPF), or simply, Permanent Force (PF).

On 19th May, 1893 the Western Australian Government forwarded Colonial Joint Defence Account Indent No. 45 to London for the supply of all articles of uniform, kit, buttons and badges etc. to equip the Permanent Force Artillery. These articles were of standard Royal Artillery pattern and the helmet, shoulder and belt buckle insignia were apparently identical to the South Australian style, except that the word "Western" and the letter "W" replaced the word "South" and the letter "S" of the South Australia insignia. The indent included an order for two "Staff Sergeant's, RA" pattern swords, scabbards and knots and two revolvers, "Webley", with cases and ammunition pouches (see Figures 1 and 2). No arms for the 26 enlisted men were included in the order.

The South Australians spent their initial months preparing the parade ground, clearing bush and undertaking the backbreaking task of mounting the guns. The men are shown on parade in a photograph (Figure 3), taken circa 1895, wearing the WAPF uniform. The photograph is probably one of the last taken of the Permanent Force while...
it still included South Australians, as most of these men had left by 1896. In the photograph the senior non-commissioned officer is wearing a sword and the men are armed with Martini-Henry Artillery Carbines and Pattern 1879 Artillery Sword.

Figure 1  Staff Sergeant’s sword and scabbard of the type purchased for the Permanent Force in 1893. (From the List of Changes in British war material).

Figure 2  Webley revolver of the type purchased for the Permanent Force non-commissioned officers in 1893. (From the List of Changes in British war material).

Figure 3  The Permanent Force at Albany, circa 1895. These men are armed with the Martini-Henry Artillery carbine and the Pattern 1879 Artillery sword bayonet. (Photo courtesy of Army Museum of Western Australia).

Arms of the South Australian volunteers

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Figure 4 Martini-Henry Artillery carbine Mark I issued in South Australia to the volunteers who formed the first gun crew to man the Permanent Force establishment at Albany, Western Australia in 1893. Carbine PMF 110, now in Western Australian Museum collection. (Photo D. Elford, Western Australian Museum).

Figure 5 Pattern 1879 Artillery sword bayonet which accompanied the Martini-Henry Artillery carbines to Albany in 1893. Bayonet number 101, in relic condition. (Photo J. Carpenter, Western Australian Maritime Museum).

Bayonets. It is the identification of these Martini-Henry carbines and Pattern 1879 bayonets that form the focus of this study.

THE ARMS

The arms under discussion are the Martini-Henry Artillery Carbine Mark I, which was introduced in 1879 as a short, light firearm for the use of artillery troops (see Figure 4). The Pattern 1879 Artillery sword bayonet was introduced in the same year as a long bladed sword bayonet with a sawtoothed back edge for use as a saw in cutting saplings and brush when emplacing the guns (see Figure 5). These artillery carbines and their predecessor, the cavalry carbine, were widely used in the Australian colonies, South Australia alone purchasing in excess of 800 of both types.

A number of Martini-Henry Artillery carbines have been noted in Western Australian collections bearing South Australian ownership markings. Interestingly, these carbines also bear markings and other evidence that sets them apart from known South Australian marked examples found in South Australian collections. In the authors estimation, these differences identify the Western Australian examples as being South Australian carbines that have been on issue in Western Australia. Three carbines have been located; one in the Western Australian Museum collection (W 175), and two in a private collection. In addition, three Pattern 1879 bayonets bearing South Australian and other markings related to these PMF carbines have been located in Western Australian collections. Two bayonets are in the Western Australian Museum collection (W 1099, T 418), and one in a private collection.

The Carbines

An examination of the carbines confirms the following common features; all are Artillery pattern carbines fitted with a barrel band lug to take the Pattern 1879 Artillery bayonet. On all is found, in the centre of the right face of the action body (see Figure 6), the usual Enfield manufacturing details of a “crown over V.R”, (the Royal cipher), over “Enfield” over the date, denoting that the carbines were made to British

Figure 6  The marks and numbers on the right side of the body of PMF carbine 110. The Enfield manufacturing details and the inverted “L” mark which was inflicted in W.A. and now defaces them. The original South Australian issue marks, "broad arrow / S.A / 541" are in the top right hand corner. (Photo D. Elford, Western Australian Museum).

Figure 7  The ownership initials and stand numbers "PMF / 110" stamped into the wooden butt of a Permanent Force carbine once on issue at Albany. The faint remains of the Enfield manufacturer's roundel can be discerned to the right of the numbers. (Photo D. Elford, Western Australian Museum).
government (War Department), contract at Enfield on certain dates (in the 1880's). Below the date, on two of the three specimens, is found the lock viewer's mark, and under this the letters and numerals "I.C.1"; the Roman numeral "I" signifying Mark I, the "C" signifying Carbine, and the Arabic numeral "1" signifying a 1st Class arm. In the top right hand corner of the body, is found stamped the ownership marks of the colony of South Australia. These ownership marks consist of a "broad arrow over S.A", impressed at the time of manufacture, under which (in the case of these specimens), are three digit stand numbers, punched in at the time of issue in South Australia. The stand numbers are "541, 546" and "608".

In addition to the marks mentioned above, each body bears a deeply struck inverted "I" shaped indentation in the centre of the right hand side markings, with a correspondingly deep "half moon", or "C" shaped indentation on the opposite (left), face of the body. These marks were inflicted at the time of disposal from service by holding the body, right hand face down, on the corner of an anvil or some other hard square cornered object and striking the left (uppermost) face of the body with a heavy round faced hammer. The hammer blow "squeezed" the body and left the inverted "I" and the "C" shaped indentations on opposite faces of the body. This defacement served the dual purpose of "cancelling" the sovereign's ownership cipher, while simultaneously rendering the firearm inoperable. This procedure apparently resulted from a short-lived Western Australian government policy of deliberately rendering a military firearm unserviceable prior to sale or disposal to the public, probably in response to an Imperial military circular to all colonies, dated 27 August 1897, requesting that certain arms no longer required by the colonies be destroyed rather than sold.  

The carbines are also marked on the right side of the wooden butt with the usual Enfield manufacturer's roundel over the Arabic numeral "1", or signifying a 1st Class arm. In addition, just above, or to the left of this roundel, is found the stamped letters "PMF" over a stand number of two or three digits (see Figure 7). Two of the three carbine stand numbers are "107" and "110", the third specimen being in relic condition, this number is no longer discernible. The letters "PMF" signify the Permanent Military Force and the stand numbers relate to the issue of these particular carbines to the Permanent Force. It will be seen therefore that these carbines have two sets of stand numbers, one recording their initial issue to the South Australian volunteer artillery, and one recording their subsequent issue to the Permanent Force.

The Bayonets  
The three bayonets noted are all standard Pattern 1879 Artillery sword bayonets designed to accompany the Martini-Henry Artillery carbine (see figure 5). Two of these three specimens have a small "broad arrow over S.A" mark stamped into the back of the blade tang between the leather grips, signifying ownership by the colony of South Australia. All have a two or three digit stand number stamped into the front of the knuckelbow, below the base of the blade (see figure 8). Numbers noted are 97, 101 and 110.  

DISCUSSION  

In a study of the issue and marking of military firearms in colonial Western Australia^ no evidence could be found to indicate that any form of carbine was ever purchased and issued to colonial volunteer artillery corps. Instead it was definitely found that only conventional long arms were on issue, and then generally only on loan from the rifle corps when needed for musketry practise. The one exception to this finding was the issue of Martini-Henry Artillery carbines to the Permanent Force artillery at Albany, but no evidence of the actual purchase of these arms by the government of Western Australia has been found. 

\footnote{Temple B.A. and Skennerton I.D., \textit{Treatise on the British Military Martini Vol. III}, Temple, Kilcoy Australia 1995. These markings are comprehensively described. Some examples of carbines manufactured at Enfield in 1881 are noted as lacking the lock viewer's mark, and the Mark and Class indicators as in the case of one of these specimens.}

\footnote{Op. Cit., Harris, p. 110. The request that arms be destroyed actually related to a special lot of converted Martini-Enfield .303 cal. rifles, rather than these obsolete .450 cal Martini-Henry carbines. However, Army General Order 296 of 24th Dec., 1903 shows that during 1904, all of the Martini-Metford and Martini-Enfield .303 rifles and Martini-Henry .450 rifles were recalled to store. Of the handful of surviving rifles of each type examined by the author, only the Martini-Metford .303 rifles and the Martini-Henry .450 carbines have the defaced bodies while the Martini Enfield and Martini-Henry rifles do not. The author believes that the damaged arms were sold as surplus and most were probably broken up for parts, while the Martini-Henry and Martini-Enfield arms were sold to the rifle clubs in accordance with Army General Order 266 of 18 Feb.,1904, and thus survived undamaged. (*Army Museum of WA Archives, General Orders 1903-1909).}

\footnote{Photographing the markings of the excellently preserved bayonet specimens in the WA Museum collection was not possible, so this example in poor condition was of necessity used for illustration. This small mark on the specimen chosen was too deteriorated to reproduce, so the reader is referred to a photograph of this mark illustrated on p. 84 of \textit{The Military Small Arms of South Australia 1839-1961}, by Harris.}

\footnote{Numbers noted on the arms include 97, 101, 107, 110. It is not known why this sequence of numbers were chosen instead of numbering from 1 to 26 as one would expect for the 26 arms on issue.}

found. Based on the knowledge that no Martini-Henry carbines were ordered by Western Australia but that the first Permanent Force gun crew was from South Australia, and that these South Australians are depicted in a contemporary photograph (Figure 3), armed with these carbines and bayonets, it was tentatively suggested that these S.A. / PMF marked carbines were of South Australian origin, brought by the first Permanent Force gun crew and left here when they departed.

Evidence which supports this interpretation includes the following considerations:

The two sites selected by the Joint Defence scheme for manning by the Permanent Force, were Thursday Island and Albany, establishing that Albany was a PMF site.

The first Permanent Force gun crew for Albany was recruited and trained in the colony of South Australia as South Australia was a member of the Joint Defence scheme whose contribution included providing a fully trained gun crew.

Records show that the Permanent Force consisted of 26 men and two senior non-commissioned officers. Records also show that when the crew were supplied with their kit and equipments in 1893, only the two non-commissioned officers had arms provided (swords and revolvers), suggesting that the 26 men were already supplied with arms.

A contemporary photograph of this crew shows them armed with Martini-Henry Artillery carbines and Pattern 1879 Artillery bayonets, confirming that such arms were definitely issued at Albany.

The Dominion Returns of 1904 lists 26 Martini-Henry .450 carbines and "some Pattern 1879 bayonets" in store. The quantity of 26 carbines corresponds exactly with the 26 enlisted men of the Permanent Force at Albany. As the Returns also include Pattern 1879 bayonets, which only fit the Martini-Henry Artillery carbine, it is safe to conclude that the Martini-Henry carbines listed in the Returns are in fact Artillery carbines. As these 26 carbines are the only carbines of any type

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endnotes:

1 Rawlin Library, WA Statistical Register, Naval and Military Returns 1895
2 Dominion Returns for Land Forces to 31st December, 1904 quoted in private correspondence by D. Skennerton (18th March 1992).
Arms of the South Australian volunteers

Table 1  Details of SA / PMF marked artillery carbines and bayonets.

<table>
<thead>
<tr>
<th>Artillery Carbine</th>
<th>Date of Manuf.</th>
<th>SA Stand Number</th>
<th>PMF Stand Number</th>
<th>Body</th>
<th>Patt. 1879 Bayonet</th>
<th>Ownership Mark</th>
<th>PMF Stand Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 175</td>
<td>1880</td>
<td>541</td>
<td>110</td>
<td>Damaged</td>
<td>W 1099</td>
<td>SA</td>
<td>97</td>
</tr>
<tr>
<td>Private</td>
<td>1880</td>
<td>546</td>
<td>107</td>
<td>Damaged</td>
<td>T 418</td>
<td>SA</td>
<td>101</td>
</tr>
<tr>
<td>Private</td>
<td>1881</td>
<td>608</td>
<td>?</td>
<td>Damaged</td>
<td>Private</td>
<td>SA</td>
<td></td>
</tr>
</tbody>
</table>

recorded for Western Australia they must be those on issue to the 26 Permanent Force artillerymen, and now (1904) recalled to store.

It can be seen from the foregoing archival records that there is no doubt 26 Martini-Henry Artillery carbines and Pattern 1879 Artillery bayonets were on issue to the 26 Permanent Force artillerymen at Albany and that they were still in military hands in 1904.

The question naturally arises as to how it can be demonstrated that the three carbines and bayonets located and described above are in fact the survivors of those 26 carbines and bayonets found in the archival record?

There are a number of important factors which point to these specimens being the survivors of the 26 Albany carbines.

Firstly, these specimens are all artillery carbines and the presence of the South Australian ownership mark and stand numbers together with the second, PMF, stand numbers confirms that these carbines and bayonets were standard issue South Australian owned arms until they were reissued to the Permanent Force. It is known that the Permanent Force gun crew for Albany was recruited and trained in South Australia, therefore it is probable that such a force would, if trained and armed in South Australia, be issued artillery pattern arms which bear both South Australian and PMF markings. Secondly, the letters “PMF” stand for Permanent Military Force, an exclusively South Australian title, the Western Australian equivalent being “WAPF” or “PF”. However the letters “PMF” and the stand numbers have never been noted on South Australian located carbines, they have only been noted on carbines which have been located in Western Australia. Similarly the PMF stand numbers which also appear on the bayonets have only been noted on South Australian marked bayonets located in Western Australia, not on identical South Australian marked bayonets located in South Australian collections. These letters and numbers therefore, although of definite South Australian origin, appear exclusively in Western Australia, indicating that this particular PMF marked group of carbines and bayonets were only ever on issue in this colony. It should be noted also that as no WAPF or PF marked arms have been found, it is apparent that these S.A / PMF marked carbines satisfied the small arms needs of the Permanent Force in Western Australia during the period 1893-1901. Thirdly and of utmost importance, these carbines all bear the inverted “L” and the “C” marks denoting deactivation prior to sale. This procedure is known to have occurred in Western Australia prior to the disposal of our Martini-Metford rifles, and was evidently applied to these carbines also. So far as is known, only W.A. colonial arms have been consistently found to bear these marks and certainly no South Australian arms other than these PMF specimens have been found deactivated in such a manner. These damage marks therefore are visible testimony to the link between these South Australian PMF marked arms and Western Australian issue.

CONCLUSION

The absence of a record of purchase of Martini-Henry Artillery carbines and Pattern 1879 Artillery bayonets by Western Australia to arm the Permanent Force at Albany, allied to the knowledge that these particular arms were definitely on issue there, led to a desire to locate, examine and explain the specimens described above. It is felt that an analysis of the various marks described, the analysis of the physical condition of these arms and of the archival record, establishes that these carbines and bayonets were at one time on issue to the South Australian Artillery corps and subsequently to the Permanent Force in Western Australia, after which they were disposed of here as deactivated surplus. It is felt that these three carbines and bayonets are the few survivors of the original 26 carbines and bayonets of the Permanent Force. These arms form a valuable historical link between the South Australian volunteers, Western Australia and the implementation of Australia's first Federal defence scheme. It is to be hoped that in due course the pair of swords and Webley revolvers purchased for the non-commissioned officers will be located to complete this study.

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Seabird breeding schedules at the Pelsaert Group of islands, Houtman Abrolhos, Western Australia between 1993 and 1998

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Abstract - The timing of breeding of seabirds at the Pelsaert Group, Houtman Abrolhos, Western Australia was recorded between 1993 and 1998. Most seabirds bred between August and April, although the commencement of laying may in some species vary dramatically from one year to the next.

INTRODUCTION
Many biologists visiting the Houtman Abrolhos, have reported on the breeding of seabirds here (Gibson 1908, Conigrave 1916, Alexander 1922, Sandland 1937, Serventy 1943, Tarr 1949, Ealey 1954, Warham 1956, Storr et al. 1986). More recent visits have concentrated on the sizes of breeding populations, particularly on Pelsaert Island (Fuller and Burbidge 1981, Burbidge and Fuller 1989, and Fuller et al. 1994). This paper aims to document the breeding seasons of seabirds at the Pelsaert Group, Houtman Abrolhos, as accurately as possible between September 1993 and January 1998. In this paper, the breeding season will be considered to include all activities from nest-site acquisition to the fledging of young. This information is essential when developing suitable management strategies for any increase in visits to the Houtman Abrolhos by different user groups. It also provides an insight into the effects of inter-annual variability in ocean currents and changes in food availability.

METHODS
The Houtman Abrolhos is an archipelago of approximately 120 islands 60 km off the coast of Geraldton, Western Australia (Figure 1). The three major groups are the Pelsaert Group, to the south, the central Easter Group and the northern Wallabi Group. Further north, still, lies the solitary North Island.

The Pelsaert Group comprises 47 islands that lie within the lagoon formed by the rim of, Pelsaert Island on the east, and Half Moon Reef, a barrier reef, on the west. The islands are scattered to the north, amongst inner reefs, platforms and sandy shallows. Most records are for Pelsaert Island, which supports the most diverse number of breeding seabirds in the Houtman Abrolhos, with some additional information from other islands within the Pelsaert Group. Pelsaert Island (28°56'S, 113°58.30'E) is the southernmost island of the Houtman Abrolhos, the third largest (120 ha) and the longest (12km). It is built on a foundation of coral reef limestone and is composed almost wholly of sedimentary rocks derived from beachcast coral limestone and the skeletal remains of molluscs and corals (Collins et al. 1993).

Thirteen species of seabird breed regularly on Pelsaert Island. They include two species of noddy (Common Noddy Anous stolidus and Lesser Noddy A. tenuirostris), six terns (Caspian Tern Sterna caspia, Crested Tern Sterna bergii, Sooty Tern S. fuscata, Bridled Tern S. maletetus, Roseate Tern S. dougallii and Fairy Tern S. nereis), two gulls (Pacific Gull Larus pacificus and Silver Gull L. novaehollandiae), two shearwaters (Wedge-tailed Shearwater Puffinus pacificus and Little Shearwater P. assimilis), and the White-faced Storm Petrel Pterodroma marina. The Red-tailed Tropicbird Phaethon rubricauda occasionally breeds on Pelsaert Island. The Pied Cormorant Phalacrocorax varius also breeds on an adjacent island.

Figure 1  Locality map showing the position of the Houtman Abrolhos in relation to Western Australia, and the position of the three major island groups and locations referred to in the text.
Seabird breeding schedules at the Houtman Abrolhos

RESULTS

The following accounts summarise the breeding chronology of each seabird recorded breeding between September 1993 and April 1997. Figure 2 shows the periods of arrival, incubation, nestlings and departure for seabirds in the Pelsaert Group.

Wedge-tailed Shearwater

The first report relating to seabirds at the Houtman Abrolhos was from the log of Adriaen van der Graff, the second mate of the Dutch ship Zeewyk, wrecked at the Pelsaert Group in July 1727. He recorded the arrival of the first Wedge-tailed Shearwaters on Gun Island, where the survivors were camped, on the evening of 20 August 1727 (O'Loughlin 1969). Over 250 years later, visits to the Houtman Abrolhos in late August found no evidence of breeding (O'Loughlin 1966, Tarr 1949). Birds return in the second half of August to excavate burrows (Storr et al. 1986). Visits in the past confirm the commencement of laying in mid-November and the pre-laying exodus. Gibson (1908) reported that laying commenced sometime between 12–19 November 1907, Sandland (1937) found fresh eggs on 16 November 1936 after witnessing the end of the pre-laying exodus, Alexander (1922) recorded fresh eggs during his visit in November 1913 and the Storr-Johnstone Data Base (Western Australian Museum) records egg laying on 13 November.

Wedge-tailed Shearwaters were already visiting their rookeries by night in early September. They were observed in large numbers in the seas adjacent to the Houtman Abrolhos during a survey aboard the R. V. Franklin on 15 August 1996. Wedge-tailed Shearwaters continue to visit the island at night until early November of each year when most breeding adults vacate the island during their pre-laying exodus, as elsewhere (Garkaklis et al. in press). The first breeding adults returned to Pelsaert Island on the evening of 16 November 1994 to commence laying. Most eggs were laid by early December of each year and chicks were hatching on 15 January 1995. Large,
downy young with some development of the primaries were found on 22 March 1997. By 21 April 1997 most nestlings were well grown, with about 20% body down, nearly fully grown primaries, beaks and tarsi. The first young fledged on 22 April 1997.

**Little Shearwater**

Adults return to breeding islands in April, commence laying in June and young usually fledge in November (Storr et al. 1986). Gibson (1908) found fully grown young in November. Few breeding attempts by Little Shearwaters were recorded, mainly due their scarcity and winter breeding time. On 3 October 1995 I found four burrows amongst low sand dunes at the northern end of Pelsaert Island; two contained a single, large downy nestling, a third contained a pair of adults and the fourth was empty. On 25 April 1997, tracks of Little Shearwaters were found around burrows on Stick Island and Pelsaert Island, although no burrows had been excavated.

**White-faced Storm Petrel**

White-faced Storm Petrels return to the Houtman Abrolhos from wintering grounds in the north-western Indian Ocean between April and September (Storr et al. 1986, Surman 1994a, Marchant and Higgins 1990). All twenty burrows of this species checked on 29 September 1994 at Stick Island were unoccupied, but there were fresh tracks throughout the colony. Storr (1966) found empty burrows on Wallabi Island during a visit in April 1959 at a time when the young had already fledged and well before adults return for the next breeding season.

**Red-tailed Tropicbird**

Breeding by Red-tailed Tropicbirds has been irregular, the last recorded attempt being a single nest in December 1988 (Fuller et al. 1994). Red-tailed Tropicbirds are regular visitors during spring and summer to Pelsaert Island. Two adults were at the southern end of Pelsaert Island on 9 October 1993, three on 21 October 1996, seven and five adults engaged in display flights on 7 and 9 December 1996 respectively, three adults were present on 3 and 5 February 1997, a single adult was observed on 17 October 1997, five on 1 December and six on 5 December 1997. Only a single nest was recorded on Pelsaert Island with one egg laid some time between 12 December 1996 and 31 January 1997. On 19 March 1997 the nest was deserted with the remains of the egg still present and the body of one of the adults nearby.

**Pacific Gull**

Pacific Gulls breed between August and October (Storr et al. 1986) with many records of large runners or fledglings during visits in November (Alexander 1922, Gibson 1908, Garstone 1978, Warham 1956, Burbidge and Fuller 1989). During the 1991/92 summer, eggs were laid from mid-August and young fledged from late November (Surman 1994b).

Pacific Gulls are resident at the Houtman Abrolhos throughout the year. Most nests contained two eggs during each year of this study (clutch size 1(10), 2 (28)), estimated to have been laid as early as 17 August in some years, with hatching taking place from 16 September until late-October. Of ten nests monitored regularly during 1995, 16 of the 17 eggs hatched and one was addled.

**Silver Gull**

Silver Gulls are resident in the Houtman Abrolhos all year, and breed during autumn and spring (Storr et al. 1986). Breeding during autumn coincides with the breeding of Roseate, Crested and Fairy Terns and the presence of rock lobster fisherman, who provide an increased food source through discarded bait and food scraps. Spring breeding appears to coincide with breeding by Lesser Noddies, Common Noddies and Sooty Terns. Spring populations of Silver Gulls are smaller and breed at different locations from autumn populations, even though their natural food source is more abundant at this time. Spring-breeding silver Gulls commence laying from late August, hatch during late September and fledge in November and December. Autumn-breeders lay in late March-early April and fledge young by late June.

**Caspian Tern**

Caspian Terns are solitary nesters throughout the Houtman Abrolhos, except for colonies of up to 80 nests on West Wallabi Island (Wallabi Group, Storr et al. 1986), 40 nests on Leo Island (Easter Group, Fuller et al. 1994) and a smaller but more recent colony of six pairs at Big Lagoon on Pelsaert Island. Most earlier accounts agree with the observations below, although O’Loughlin (1969) found eggs in January 1968 at a time when most young would have fledged. Caspian Terns usually lay two eggs (clutch size 1(7), 2(20)) during spring. Eggs are laid between 20 August and 30 September with most laid in the first half of September. Chicks hatched between late September and mid-October and fledged from late October. At seven nests, each containing two eggs, followed until hatching in 1995, ten eggs (71%) hatched, two were addled and two met an unknown fate.

**Crested Tern**

At the Houtman Abrolhos Crested Terns, like...
Silver Gulls, Roseate Terns and Fairy Terns, may breed during autumn or spring/summer. Dunlop (1985) found that individual Crested Terns in the Fremantle area of Western Australia tended to breed at the same time each year, making autumn and spring/summer populations distinct. It is uncertain if this applies to Houtman Abrolhos Crested Terns. Other studies have reported eggs as early as late August (O’Loughlin 1966) and September (Storr 1966) at the Wallabi Group and, on Pelsaert Island, Garstone (1978) found small chicks during late October, suggesting that laying commenced two weeks earlier on Pelsaert Island during 1977 than reported here for 1993-1997. Autumn-nesting begins during late March.

A group of 80 Crested Terns, each with single eggs, commenced laying on 24 March 1997 on Stick Island. Spring/summer breeding by smaller colonies of up to 250 pairs begins around 15 October at various localities on Pelsaert Island. In 1991, 1995 and 1996 each of these smaller colonies failed completely. A larger colony at an established nesting area where up to 1500 pairs may breed (Fuller et al. 1994) laid highly regularly and synchronously, commencing on 16 October 1993, 18 October 1994, 22 October 1995 and 23 October 1996. This colony relocated approximately 400m west of the original site and laying commenced between 30 October and 1 November 1997. Laying continued until mid to late-November and by mid-December some eggs were still being incubated at the same time as mobile young up to three weeks old dispersed along the rocky shore. Some later breeders were still raising large young by early February.

Bridled Tern

Few visitors have recorded laying by Bridled Terns. No eggs were present during Garstone’s (1978) visit in October nor Alexander’s (1922) in November, or Sandland’s (1937) visit in early November 1936. Fresh eggs were observed by Fuller and Burbidge (1981) on 27 November 1980. Storr et al. (1986) sites R.E. Johnstone’s observations of 17 August 1980 of juveniles on Newman Island that would have come from eggs laid in late June.

Bridled Terns first return to their nesting grounds at night before returning during daylight to secure nest sites. The first birds were observed during the evenings of 7 October 1993 and 1994, and on 2 October 1995. Bridled Terns were already present by day on 15 October 1996 and 1997. Laying commenced on 22 November and continued well into January, although one egg was just hatching on 22 March 1997 on Newman Island. Chicks usually fledged by mid-March and mid-April. A further check for a new wave of nesting by Bridled Terns on Newman Island on 27 April 1997 revealed 12 freshly laid eggs. Any young from these eggs would not have fledged until mid-July, well after most Western Australian Bridled Terns had departed in May for wintering grounds in the Sulawesi Sea (Dunlop and Johnstone 1994). This population of Bridled Terns is currently being investigated to determine if it is resident or consists of summer breeders relaying after a failed initial attempt or comprises recruits nesting for the first time.

Sooty Tern

This is the most numerous seabird breeding in the Pelsaert Group. Sooty Terns are highly synchronous breeders (Feare 1976), with only a few early eggs each year before the main laying period. Although some earlier accounts (Sandland 1937, Tarr 1949) indicate that Sooty Terns usually lay in October, as found from 1993-1995, other visitors (Garstone 1978) reported laying commencing as late as 26 October, similar to 1996/97. Similarly, both Burbidge and Fuller (1989) and Warham (1956) also found during visits in 1981 and 1994 respectively that laying commenced in late October and Storr et al. (1986) reported laying dates of October-November.

Numbers had built up at the southern end of Pelsaert Island by the time of my first visit each year in early September. Laying commenced on 25-27 September each year between 1993 and 1995, with most eggs laid during early October, but did not commence until 24 October during 1996 and 3 December 1997. Hatching began in late October and by mid January large nestlings and free-flying young were present, some already participating in foraging excursions. The last birds departed Pelsaert Island in late April 1997 although most birds had already left on their northward migration by mid-March of each year. No young were recorded from the 1997/1998 breeding season.

Common Noddy

Common Noddies return to the Houtman Abrolhos in August. On 3 September 1994 and 1995 Common Noddies were already defending sites, building nests, and some had fresh eggs. Laying commenced during late August or early September during most years of this study, but did not begin until early November in 1996 or until late November 1997, despite adults having returned to the area in August. Young hatched from October onwards in some years and most had fledged by January. During the 1996/97 season, some fledglings were still roosting on Pelsaert Island during the day on 25 April 1997.

Lesser Noddy

Lesser Noddies are resident at the Houtman Abrolhos. Previous visits recorded laying between
mid-August and late December (Storr et al. 1986). During the 1991–1994 breeding seasons laying began in late August, with most eggs laid in September and October. However, laying was delayed until mid-October during 1995 and until early-November in 1996 and 1997. The laying period is typically protracted, extending for more than 100 days when laying commenced in late August (Surman and Wooler 1995). Young were present from early October and fledged from mid- November onwards.

Fairy Tern

Fairy Terns occur at the Houtman Abrolhos throughout the year, although numbers may decline during winter (Storr et al. 1986). Laying commenced on 24 November in 1991 (Surman 1994b), early November (Gibson 1908, Alexander 1922) or late October in other years (Garstone 1978). Storr et al. (1986) lists breeding from late October to mid-February. The earliest attempts at breeding during this study occurred on 5 November 1995 when seven nests were observed on Burnett Island. On 4 February 1997 some nests contained eggs and young nestlings on Pelsaert Island.

Roseate Tern

Roseate Terns breed during summer and autumn at the Houtman Abrolhos, although it is unclear whether the two breeding groups belong to distinct populations. Spring/summer breeders commence laying in early November. A dozen birds were on eggs on an islet to the north of Robinson Island and 30 more were in attendance on 5 November 1995. A colony (500 nests) of Roseate Terns nested at Wreck Point, Pelsaert Island, in 1991, 1993, 1994, 1995 and 1997. Laying had commenced at this site by 7 November 1995 with a further 250 adults in breeding plumage defending sites; by 15 November 1995 it was estimated to contain 350–500 nests.

Laying commenced at the same time on adjacent Square Island from 1993 to 1997. On 16 November 1995, approximately 200 birds nested on Square Island. On 29 November 1994 this colony contained one or two egg clutches, while, at the same time, a smaller colony at the Coral Patches had clutches of 1–3 eggs, and nestlings 1–7 days old. During 1996, Roseate Terns bred at a site 2 km north of Wreck Point, with approximately 1000 nests by 10 December 1996, mostly single egg clutches. By 2 February 1997, the colony had been abandoned leaving the remains of well-developed eggs and bodies of nestlings less than 5 days old.

Autumn-breeding populations of Roseate Terns began displaying at potential nesting sites by mid-March. Nest-sites in autumn tended to differ from those used in summer. Breeding was recorded on Post Office Island in April 1995, 1996 and 1997, with laying starting on 25 April 1997; by 20 May 1997 chicks were hatching. A colony of 80 nests on Newman Island, with approximately 350 adults in attendance was first noticed on 19 April 1997 (B. Suckling pers. comm.) but was unsuccessful.

DISCUSSION

Most seabirds at the Houtman Abrolhos breed during spring/summer. Some Roseate Terns, Crested Terns, Bridled Terns and Silver Gulls breed during autumn as well as spring/summer; it is unclear whether these represent distinct breeding populations. Spring breeding coincides with longer daylight, less frequent passage of cold fronts, lower rainfall and prevailing southerly winds (Surman 1997). Earlier observations also found that spring/summer was the busiest breeding time for seabirds at the Houtman Abrolhos (Storr et al. 1986, Fuller et al. 1994).

All species are probably annual breeders, commencing their next breeding attempt around the same time each year. However, variation in the mean annual laying date of the Lesser and Common Noddy of as much as two months appears linked to variability in the flow of the Leeuwin Current (Surman 1997).

Other years in which Lesser Noddis and Common Noddies appear to have laid later (i.e. November), were recorded by Warham in 1954, and O’Loughlin in 1968. Both species appeared to respond more dramatically than other species to variation in oceanographic conditions, perhaps because their large colony size made changes more obvious. However, other seabird species were not studied as intensively and may have been affected in less obvious ways.

Regular monitoring of seabird breeding seasons would make it possible to understand which factors, if any, influence breeding times from one year to the next and how best to ensure that seabirds are protected during their most vulnerable stages of breeding from disturbance to their nesting sites on land, or to exploitation of marine sources of food.

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Seabird breeding schedules at the Houtman Abrolhos

Michael Nikulinsky. Transport was kindly provided by Bevan Suckling, Mal Macrae and Geoff and Barbara Whitehurst.

REFERENCES


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The Volunteer Defence Corps prototype socket bayonet

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Abstract - Previously known only as a prototype drawing, three specimens of this Western Australian designed bayonet are located and described. A short description of the locale, methods employed, and personnel involved in their manufacture is presented.

INTRODUCTION
In 1939 Australia declared war on the Axis powers and commenced the total mobilisation of its armed forces. In order to free manpower for the armed forces and at the same time augment Australia's internal defence capability, it was felt that an organisation of trained, armed men should be established to assume the burden of guarding strategic communication and industrial facilities. Thus, on June 6th, 1940 the Volunteer Defence Corps (V.D.C.), was established throughout Australia under the auspices of the Returned Soldier's League (R.S.L.). Members consisted of those men who were ineligible for military service due to age limits, health or reserved occupations. In Western Australia, overall command of the R.S.L.V.D.C. rested in Brigadier General A.J. Bessel-Brown. Each of 134 R.S.L. sub-branches were formed into units. There were no established ranks. Initially uniforms were non-existent and arms were broomsticks and anything which could be "wrangled". Earliest uniforms in Western Australia consisted of W.W.I army uniforms dyed a distinctive green to distinguish these men from the regular forces. Although not recognised by the Army, Western Command provided 2400 "Westley Richards" * .310 inch calibre Martini Cadet rifles in October 1940. These rifles, originally purchased in 1908-1911 for the Commonwealth military cadet training scheme, never had an accompanying bayonet. More modern smallarms and ordnance such as mortars and machineguns could not be supplied due to the need to arm the regular forces first. As the war progressed and Japan became more of a threat, the V.D.C. role included training in conventional warfare and guerilla tactics in case of invasion. In April 1941 the Post Office Volunteer Corps and the Rifle Clubs were absorbed into the V.D.C. In June, control of the Corps passed to the Army and the Corps became part of the Military Forces, and, while still voluntary, were subject to military regulations. Western Australia was divided into four Group areas and eventually manned by numbers in excess of 12,000 men. Even though under Army control, arms and equipment remained in short supply due to the war situation. Arms consisted of .310 Cadet rifles with high-velocity bullets, and eventually, light machine guns, 3 inch mortars and converted W.W.I German medium machine guns. By October 1942, war production had caught up with demand and modern smallarms, equipment and uniforms began to be issued to the Corps*. V.D.C. personnel came under enemy fire on occasion and rendered valuable service in many spheres of national defence before disbandment at the end of the war*

During the period mid 1940-mid 1942, when arms were almost unobtainable, many talented personnel manufactured in metropolitan and rural workshops, a variety of improvised arms such as Vickers and Lewis machine guns, 3 inch mortars and socket bayonets. It is the bayonets which are the subject of this discussion.

1 Westley Richards and W W Greener of Britain were two of the earliest suppliers of Martini Cadet rifles in the eastern states, and these names became a generic term for this type of rifle. In fact, the most common make of Martini Cadet rifle is the Birmingham Small Arms Co type. It was the B.S.A. (also of Britain), which was on issue in W.A.
2 Battye Library, Volunteer Defence Corps 1940-1945, 1903 A/1, files 1-8.
3 Accounts of actual service and the history of the Corps can be found in On Guard with the Volunteer Defence Corps, AWM, Canberra, 1944.
De Pierres, Paul. Wheatbelt Warriors, Privately Published, Wyalkatchem, WA 1993. Reference to the V.D.C. personnel responsible for the manufacture of replica Vickers and Lewis machine guns and a 3 inch mortar is made in this work. The WA Museum holds specimens of a replica Vickers, a replica Lewis and a 3 inch mortar which the author believes are probably these V.D.C. arms, but further research is necessary to be able to confirm this link.
THE PROTOTYPE SOCKET BAYONET

Until now, this socket bayonet was only known as one of a series of prototype drawings published in 1986 in a comprehensive reference book on the subject of British and Commonwealth bayonets, but it was unknown if any of the bayonets had actually been produced. According to the reference these three drawings, designated A21, A22 and A23 in the book, were submitted by local V.D.C. detachments to Perth V.D.C. headquarters in 1942 as “Bayonet for .310 Martini Rifle, Samples 1, 2 & 3”. Samples 2 and 3, were rejected and Sample 1 (A 21, see Figure 1), was forwarded to Melbourne headquarters on June 26th 1942, as suitable for production. Made of spring steel, the bayonet was costed at 6/8d, and a request that the first 10,000 be sent to this state accompanied the drawings sent to the east. In late July a response was received to the effect that an eastern states design had already been chosen for production. The design chosen is not known, but the response is thought to have coincided with the breakthrough in supplying the V.D.C. with modern smallarms, bayonets and other equipment and ordnance as Australia’s war production had now expanded to meet all supply demands. It is probable that the availability of modern arms ended any further need to produce improvised weapons of any kind, and consequently the proposed V.D.C. bayonet production was abandoned.

Description

The author was aware of the prototype drawing, and was fortunate to locate an example of a socket bayonet fitting the drawing’s characteristics in the WA Museum collection (T.882), and later located two more; one in the Army Museum of Western Australia collection (104/78), and another in a private collection.

The first of these to be noted (WA Museum, T.882, see Figure 2), appeared to be identical to the prototype drawing A21 in all respects except being 22 mm shorter than the stated overall length. In a practical test, it was found that the bayonet fitted perfectly on a sample .310 Martini Cadet rifle, but not on any other comparable type of rifle.

The bayonet is the conventional triangular section spike blade welded to a tubular socket which has a manually operated, rotating locking ring. The blade is a 320 mm long section of 12 mm diameter hardened steel rod, which has been ground or finished to produce three equal width flats tapering to a “clipped”, or truncated, tip. The blade, whose three edges are sharp enough to cut, has been welded (possibly arc welded) to the socket. The socket consists of a 70 mm long section of 23 mm diameter steel tubing, which has been turned down to 20 mm to produce a rebate for the locking ring to bear against. The socket tube has been drilled or reamed out to an internal diameter of 16 mm. The locking ring is 20 mm wide, of thin flat sheet steel bent around the diameter of the socket, but is left open at the top to allow the foresight block of the rifle barrel to pass. The open topped “O” thus formed has a pair of projecting “ears” which form the thumb pieces to facilitate the locking and unlocking operations. All parts of the bayonet exhibit evidence of hand filing and the bayonet appears oil blackened. The bayonet bears no markings and is not accompanied by a scabbard.

The specimen differs from most conventional socket bayonet types in that the slot cut in the top of the socket to accommodate the foresight block of the rifle barrel, is straight (not the usual zig-zag), and the manually operated spring steel locking ring which rotates to lock against the rear of this sight block, is open at the top, rather than the usual
Volunteer Defence Corps bayonets

Figure 2 The V.D.C. socket bayonet for the .310 Martini Cadet rifle. Compare this example with drawing A 21 in Figure 1. (Photo K. Brimmell, Western Australian Museum).

Figure 3 Details of the socket, sight slot and locking ring of the bayonet in Figure 1. (Photo K. Brimmell, Western Australian Museum).

closed type (see Fig. 3). Another characteristic of this bayonet is that the rear end of the socket rests against the metal nosecap of the rifle’s forend and is held firmly against the nosecap by the rearward pressure as the locking ring presses against the rear of the foresight block. The foresight block does not come into contact with the closed forward end of the slot. The effect of this arrangement is that the forend provides firm support for a forward thrust of the bayonet, and the foresight block provides support for the withdrawal of the blade. Most conventional types of socket bayonet lock exclusively to the foresight block, which must bear all the forward and rearward stresses when in use.

DISCUSSION

The discovery of this bayonet demonstrates that an example existed, matching the V.D.C. prototype drawing in all except minor dimensional details, but the discovery did not definitely clarify the question of whether this particular bayonet was indeed made by the V.D.C. A study of the Western Australian Museum records showed that this bayonet was donated over 30 years ago by a private citizen with no apparent connection to the V.D.C., and who could not now be traced. As has been referred to in footnote 4, a 1944 document from the V.D.C. to the United Services Institute, offering to their collection “bayonets for .310 rifles” (which was accepted), is evidence that a type of V.D.C. bayonet for the .310 Martini Cadet rifle existed, but the bayonet is not in the Western Australian Museum collection. Although promising, further study was needed to determine conclusively the origins and production details of this bayonet. After informal inquiries among collectors and institutions, the author was able to examine two more specimens of this bayonet. The two subsequent bayonets were determined to be

7 Prior to the transfer of the U.S.I. collection to the Western Australian Museum, U.S.I. members were permitted to retrieve personal property, and some items listed were consequently not included in the actual transfer. As the records of the time were confused, it is also possible that this bayonet (T.882) is actually the V.D.C. bayonet in question, but was inadvertently attributed to the recorded donor.
Table 1 Specifications of the V.D.C. Socket Bayonet (in mm).

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<th>SOURCE</th>
<th>Overall Length</th>
<th>Blade Length</th>
<th>Blade Flat Length</th>
<th>Blade Thickness</th>
<th>Socket Length</th>
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exact replicas of the Western Australian Museum bayonet in all respects of shape, components, function, fabrication and finish. Dimensions of the socket in respect of muzzle ring diameter, sight slot length, rebate position and locking ring width are uniform, indicating that they were all designed to fit the .310 Martini Cadet rifle, and in fact did fit these rifles when tested. The exception to the above is found in the differences in the lengths of the flats on the blades and the lengths of the blades themselves (see Table 1). (One would perhaps expect to see discrepancies in the grinding of the blades, occasioned by hand production techniques). As with the Museum specimen, there was no connection with the V.D.C. recorded in the provenance of these two most recent specimens.

After placing an advertisement relating to this research in the local newspaper, the author received a number of responses from former V.D.C. members who had served in various detachments. Only two respondents had any knowledge of improvised bayonets being used in the V.D.C. Significantly, these two respondents were the only ones to serve in the Midland Junction detachment. Mr Harry Gratte, a former employee of the Western Australian Government Railways (W.A.G.R.), at Midland Junction during the war, was a member of the mounted section of the Midland detachment of the V.D.C. Mr Gratte described a single bayonet he had seen attached to the .310 Martini Cadet rifle standing in a rack at the Bushmead rifle range during a V.D.C. firing practice in 1942. Without prompting, Mr Gratte described the bayonet as "about 10 inches (255 mm) long, with a locking ring and a tri-form blade". Although seen in the Midland V.D.C. detachment ranks, Mr Gratte had no memory of whose bayonet it was or of any such bayonets being made at his place of work, the Midland Junction Railway Workshops. Mr Gratte left the V.D.C. in early 1943, at which time they still had the .310 rifle.

The second respondent, Mr Frank De Catania was an apprentice fitter at the W.A.G.R. workshops in Midland Junction during the war and as such was in a reserved occupation and could not enlist in the A.I.F. He was in the Midland detachment of the V.D.C. also, and described how in 1942 he had fabricated "a number of socket bayonets for the V.D.C at the Midland workshops". Without prompting, he accurately described the bayonets as having "triangular blades about nine or ten inches long (230-255 mm), with a socket and locking ring". Mr De Catania could not remember exactly if he worked from drawings, but said he made "a number; two or three, under supervision or to direction". The spring steel locking ring was shaped to the socket by him, "but tempered in the blacksmith shop". When shown photographs of the bayonet, (Figures 2 & 3), he positively identified the bayonet as being the type made at the workshops during the war. In addition, Mr De Catania recollects that "a few" of the men, including himself, then made their own unofficial versions of the bayonet. Mr De Catania's version of the bayonet was identical to the bayonets described here, except that he made his blade from a triangular file which he annealed, then ground to shape before hardening. Mr De Catania made his bayonet because he felt his .310 rifle was inadequate when he was on night sentry duty guarding the V.D.C. headquarters behind the Midland Junction Town Hall. Neither respondent could recollect any further details about the bayonets and no subsequent respondents were forthcoming.

CONCLUSION

The recollections of these two gentlemen are of great value as they positively identify the bayonets as being for the .310 Martini Cadet rifle and also link them to the V.D.C., a link that could not previously be established. The archival evidence given in the reference book is thus confirmed. All three bayonets exhibit identical shape, components, fabrication techniques, function and finish, suggesting that they were all made together as a batch or to a pattern, which tends to confirm Mr De Catania's description of making the bayonets under direction. The evidence also confirms that

1 Conversation with Mr Harry Gratte of Caversham, 19 September 1995
2 Conversation with Mr Frank De Catania of Gosnells, 19 September 1995
3 The fact that all three bayonets have been in collections for up to 20 years prior to the publication of the prototype drawing in 1986, precludes any possibility that the bayonets have been fraudulently manufactured since the drawing was published.
these bayonets were made at the W.A.G.R. workshops at Midland Junction. Because of the time of manufacture (1942), and the small number made, the author is inclined to the view that these bayonets were made as samples or prototypes in connection with the proposed V.D.C. bayonet manufacturing proposal of June–July 1942. The "issue" of these bayonets was probably confined to a few personally manufactured examples such as Frank De Catania's.

In the sense that these bayonets are substantially hand made and finished from rudimentary materials, they can be considered "crude", but in that they are of absolute functional simplicity, requiring only three parts which can be made and assembled in any small workshop by unskilled workers, they are a minor masterpiece of successful technical design. These bayonets form an important historical record of Western Australia’s wartime local volunteer defence effort.

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A catalogue of recent Cnidaria type specimens in the Western Australian Museum of Natural Science, Perth

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Abstract - This is the first published catalogue of cnidarian type material lodged in the Western Australian Museum of Natural Science. Fifty cnidarian species of the classes Hydrozoa and Anthozoa are represented in the type collection. The earliest cnidarian species described in this collection date from 1910 when alcyonacean material from the Hamburg South-Western Australian Research Expedition was published. Information is presented here on the registration and collection details of the specimens, and habitat information is given where available.

INTRODUCTION
The cnidarian collection held in the Department of Aquatic Zoology, Museum of Natural Science, Western Australian Museum (WAM), Perth, consists of over 13,300 registered specimen lots. This material includes type specimens of 50 species of Recent Cnidaria. Hydrozoan type material consists of two species of Stylasteridae. Anthozoan type material consists of 10 species of Alcyonacea, one species of Pennatulacea, six species of Actiniaria, four species of Zoanthidea and 27 species of Scleractinia. This is the first time that a catalogue of the WAM cnidarian type material has been published.

The earliest references to species represented in the WAM cnidarian type collection date from 1910 when species of Alcyonacea (Kükenthal, 1910) and Actiniaria (Lager, 1911), collected on the Hamburg South-Western Australian Research Expedition, were described. This expedition, led by W. Michaelsen and R. Hartmeyer, was undertaken in 1905 and material was collected from a number of Western Australian localities. Since then, significant contributions to the type collection have been made by Alderslade (1983, 1998), Alderslade and Baxter (1987), Cairns (1988, 1998), Carlgren (1954) and Veron (1985).

In this paper, the taxonomic sequence of the classes and orders follow Cairns et al. (1991). Families, genera and species are arranged alphabetically within each higher classification. Where the original generic assignation of a species has been revised or where the species has been synonymised, the new generic assignation is given as a heading. The original genus-species combination is provided in full beneath it. The species is placed in the family of the genus to which it now belongs. The author who revised the generic assignation of the species is noted in 'Remarks'. The spelling of genera and species has been changed, where necessary, from the original spelling to conform with ICZN rules (ICZN 1985 Article 32 c, d). Many of the earlier taxonomists referred to here did not designate a holotype but instead described type material that may have consisted of a single specimen or a series. In those cases where there was either a series of specimens, or where the number of specimens being described was unclear, the type material is designated as syntypic (ICZN 1985 Article 73 b).

In the majority of cases, two WAM registration numbers are given. The first, with the prefix WAM is the original registration number and the second, provided in square brackets with the prefix WAM Z, is the new registration number linked to the WAM computer database. Part of the old registration numbers included the last two digits of the year in which the specimens were registered. This is unsatisfactory because at some time in the future numbers would start to be replicated. A sequential numbering system has now been adopted. The prefix Z distinguishes the registration numbers of the section of Marine Invertebrate Zoology from those of other sections within the WAM. Where a specimen was not registered previously, the registration number has the WAM Z prefix but is not quoted inside square brackets. The number of specimens, the sex if known, and the method of storage, are given in parentheses after the registration number. Specimens that are described as 'wet' are stored in 70 % (v/v) ethanol. When latitudes and longitudes have not been quoted in the reference or on the specimen label, they are supplied in square brackets. Distances and
depths are cited when provided, and their metric conversion appears in square brackets. Any inconsistencies between the label, registration catalogue or published information are noted under 'Remarks'. Additional information considered useful to researchers, such as the condition of the specimens, is also presented under 'Remarks'.

Abbreviations used in this paper are as follows: ICZN, International Commission on Zoological Nomenclature; MTQ, Museum of Tropical Queensland, Townsville; USNM, United States National Museum (now the National Museum of Natural History); WAM, Western Australian Museum (now the Museum of Natural Science, Western Australian Museum), Perth.

Class HYDROZOA Owen, 1843
Order ATHECATAE Hincks, 1868
Family Stylasteridae Gray, 1847
Genus Stylaster Gray, 1831
Stylaster marshae Cairns, 1988

Stylaster marshae Cairns, 1988: 108-112, figures 1 a, e, 2 a-g.

Material Examined

Holotype number WAM 535-87 (♀; dry) [new registration number: WAM Z 925].

Paratypes number WAM 424-86 (3♀; dry) [new registration number: WAM Z 926].

Locality: Station 3 (26°07'40"S, 113°10'20"E), NW of Surf Point, Dirk Hartog Island, Shark Bay, Western Australia, under a ledge at 30 feet [9 m] depth, 5 April 1979, L.M. Marsh.

Paratypes number WAM 129-58 (2♀, 2♂; dry) [new registration number: WAM Z 927].


Paratypes number WAM 80-78 (6♀; dry) [new registration number: WAM Z 928].

Locality: Goss Passage, SE end of Long Island, Wallabi Group, Houtman Abrolhos Islands, Western Australia, in a sheltered position on a coral pinnacle at 25–42 feet [7.5–13 m] depth, 4 September 1977, S.M. Slack-Smith.

Paratypes number WAM 425-86 (2♀; dry) [new registration number: WAM Z 929].

Locality: Station 4 (26°07'40"S, 113°10'20"E), E side of reef, S of Surf Point, Dirk Hartog Island, Shark Bay, Western Australia, under ledges at 1–2 m depth, 5 April 1979, L.M. Marsh.

Paratypes number WAM 426-86 (4♀, 3♂; dry) [new registration number: WAM Z 930].

Locality: Rottnest Island [32°00'S, 115°31'E], Western Australia, donated to WAM in November 1974, E.P. Hodgkin.

Paratypes number WAM 429-86 (2♂; dry) [new registration number: WAM Z 931].

Locality: SE side of Pelsaert Island, Pelsaert Group [28°50'S, 113°55'E], Houtman Abrolhos Islands, Western Australia, on an intertidal reef platform, 13–14 December 1982, S.M. Slack-Smith.

Paratypes number WAM 130-73 (3♂; dry) [new registration number: WAM Z 932].

Locality: Green Island Reef, Rottnest Island [32°00'S, 115°31'E], Western Australia, abundant on wall of reef hole exposed to surge, 22 January 1973, L.M. Marsh and R.W. George.

Paratype number WAM 430-86 (1♀; dry) [new registration number: WAM Z 933].

Locality: SW of Gun Island, Pelsaert Group [28°50'S, 113°55'E], Houtman Abrolhos Islands, Western Australia, inside outer reef, among dead staghorn Acropora, 8 April 1976, L.M. Marsh et al.

Paratypes number WAM 427-86 (1♀, 2♂; dry) [new registration number: WAM Z 934].


Paratypes number WAM 440-86 (3♀, 3♂; dry) [new registration number: WAM Z 935].

Locality: Little Island [31°49'S, 115°43'E], off Whitford Beach, Western Australia, on roof of cave at 1–2 m depth, 13 April 1974, L.M. Marsh.

Paratypes number WAM 431-86 (2♀, 3♂; dry) [new registration number: WAM Z 936].

Locality: Inside outer reef NW of Gun Island, Pelsaert Group [28°50'S, 113°55'E], Houtman Abrolhos Islands, Western Australia, among dead staghorn Acropora at 0–1 m depth, 1 April 1976, L.M. Marsh et al.

Remarks

The specimen of WAM 129–58 was pale pink in colour when alive.

Colonies of WAM 535–87 and WAM 80–78 are broken into many pieces and fragments are broken off colonies of WAM 426–86.

One female colony from WAM 80–78 was donated to USNM (USNM 79519) and one male colony from WAM 440–86 was donated to USNM (USNM 79520).

Cairns (1988) states that there is one female in WAM 429–86, but there are two specimens present and the specimen label cites two males. Also, for WAM 130–73 Cairns (1988) states the
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sex as being female but the specimen label cites it as male.

Stylaster tenisonwoodsi Cairns, 1988
Stylaster tenisonwoodsi Cairns, 1988: 112–115, figures 1b, 3a–f.

Material Examined
Holotype number WAM 536–87 (♀; dry) [new registration number: WAM Z 923].
Paratypes number WAM 934–86 (3♀; dry) [new registration number: WAM Z 924].
Locality: Station 10, SE corner of Ashmore Reef [12°17'S, 123°02'E], Western Australia, at 6–8 m depth on an outer reef slope on the under side of Porites ledges, 15 September 1986, L.M. Marsh.

Remarks
One ♀ of WAM 934–86 was donated to USNM (USNM 79521).

Class ANTHOZOA Ehrenberg, 1833
ORDER ALCYONACEA Lamouroux, 1816 (emend. Verrill, 1866)
Family Alcyoniidae Lamouroux, 1812 (emend. May, 1899)
Genus Dampia Alderslade, 1983
Dampia pocilloporaeformis Alderslade, 1983
Dampia pocilloporaeformis Alderslade, 1983: 34–35, figures 1, 2, 4, 5.

Material Examined
Holotype number WAM 574–79 (wet) [new registration number: WAM Z 868].
Locality: Dampier Archipelago [20°33'S, 116°32'E], Western Australia, collector and date unknown.

Remarks
The location is given only as “Shark Bay” on the specimen label. It is unclear on which date the specimens were collected. In alcohol, they are olive-green in colour and the points are composed of pink sclerites.
Nepthea hartmeyeri Kükenthal, 1910
Nepthea hartmeyeri Kükenthal, 1910: 46–47, figures 9–10 and plate 3 figure 19.

Material Examined

Syntype number WAM 7178 (1; wet) [new registration number: WAM Z 863].

Locality: Station 19, Useless Inlet [26°08'S, 113°21'E], Shark Bay, Western Australia, at 7 m depth, 13 September 1905, W. Michaelson and R. Hartmeyer (Hamburg SW Australian Expedition).

Remarks

It is part of the type series and is a very small fragment of a colony.

Family Isididae Lamouroux, 1812

Subfamily Circinisidinae Grant, 1976

Genus Annnisis Alderslade, 1998

Annnisis sprightly Alderslade, 1998


Material Examined

Holotype number WAM 385–79 (wet) [new registration number: WAM Z 869].

Locality: Station 33M (29°06.7'S, 113°58.5'E to 29°07.5'S, 114°0'E), approximately 92 km west of Dongara, Western Australia, dredged at 91.4 m depth, 19 February 1976, M.V. Sprightly Dredging Cruise.

Genus Zigtiisis Alderslade, 1998

Zignisis lornae Alderslade, 1998


Material Examined

Holotype number WAM 26–74 (wet) [new registration number: WAM Z 871].

Paratype number WAM 23–74 (1; wet) [new registration number: WAM Z 872].

Locality: NW of Rottnest Island [32°00'0'S, 115°30'E], Western Australia, dredged from amongst sponges at 37 fathoms [67.7 m], 12 August 1962, R.R. Wilson on F.V. Bluefin.

Paratype number WAM 395–79 (1; wet) [new registration number: WAM Z 873].

Locality: NW of Rottnest Island [32°00'0'S, 115°30'E], Western Australia, dredged from amongst sponges at 37 fathoms [67.7 m], 12 August 1962, R.W. George on F.V. Bluefin.

Paratype number WAM 419–80 (1; dry) [new registration number: WAM Z 922].

Locality: Northwest of Rottnest Island [32°00'0'S, 115°30'E], Western Australia, at 110 ft [33.5 m] depth, December 1979, C. Bryce.

Remarks

The specimen is in several small pieces.

Order PENNATULACEA Verrill, 1865

Family Pteroeididae Kolliker, 1880

Genus Sarcoptilus Gray, 1848

Sarcoptilus rigidus Williams, 1995

Sarcoptilus rigidus Williams, 1995: 24–25, figures 7c–d, 8, 9.

Material Examined

Holotype number WAM 363–31 (wet) [new registration number: WAM Z 1142].

Paratype number WAM 364–31 (1; wet) [new registration number: WAM Z 1143].

Locality: Beach at Jarrad Street, Cottesloe [31°59'S, ...
Order ACTINIARIA

Family Actiniidae Rafinesque, 1815

Genus *Bunodactis* Pax, 1920

*Bunodactis maculosa* Carlgren, 1954


**Material Examined**

*Syntypes* number WAM 153–56 (2; wet) [new registration number: WAM Z 888].

Locality: Mangles Bay [32°16'S, 115°43'E], Cape Peron, Western Australia, under stones, 13 September 1952, L.M. Marsh.

**Remarks**

The locality was given incorrectly as Point Peron in Carlgren (1954). When alive, the column is a light grey-brown in colour with vertical rows of white spots and the tentacles and oral disc are mottled light brown and white. Part of one of the specimens is embedded in wax.

Genus *Isactinia* Carlgren, 1900

*Isactinia carlgreni* Lager, 1911


**Material Examined**

*Syntype* number WAM 7122 (1; wet) [new registration number: WAM Z 885].

Locality: Station 5, Denham [25°56'S, 113°32'E], Shark Bay, Western Australia, 9 June 1905, W. Michaelsen and R. Hartmeyer (Hamburg SW Australian Expedition).

**Remarks**

The location is written incorrectly as “Sharks Bay...” in Lager (1911). The collection date is given as 8–9 June 1905 but the specimen label cites 9 June 1905 as the only collection date.

Genus *Oulactis* Milne-Edwards, 1851

*Saccactis mcmurrichi* Lager, 1911


**Material Examined**

*Holotype* number WAM 18–84 (f; wet) [new registration number: WAM Z 875], figures 3–4.

Locality: Station S02/82/46 (18°41'S, 116°45–47'E), 145 nautical miles [269 km] NW of Port Hedland, Western Australia, Engel trawl at 506–508 m depth on muddy substrate, bottom temperature 8.5°C, 13 April 1982, L.M. Marsh on R.V. *Soela*.

*Paratypes* number WAM 21–84 (2; wet) [new registration number: WAM Z 876], figures 1, 3.

Locality: Station COR/83/04 (18°06’S, 118°10’E), SW of Imperieuse Reef, Rowley Shoals, Western Australia, beam trawl on mud substrate at 353–356 m depth, 17 August 1983, P. Berry and N. Sinclair on F.V. *Courageous*.

*Paratype* number WAM 177–83 (1; wet) [new registration number: WAM Z 877]

Locality: Station S02/82/37 (18°20’S, 118°00’E to 18°19’S, 118°19’E), 124 nautical miles [230 km] NWW of Port Hedland, Western Australia, Engel trawl at 320 m depth, bottom temperature 11.9°C, 10 April 1982, L.M. Marsh.

**Remarks**

The hermit crab with WAM 177–83 was a specimen of *Parapagurus* sp.

Family Sagartiiidae Gosse, 1858, s. str.

Genus *Actinothoe* Fischer, 1889

*Actinothoe glandulosa* Carlgren, 1954


**Material Examined**

*Syntypes* number WAM 150–56 (1; wet) [new registration number: WAM Z 887].

Locality: Stat. 55, Bunbury Bez., nordnordöstlich von Casuarina Point, Western Australia, Mieresstrand. (Station 55, NNE from Casuarina Point [33°18’S, 115°38’E], near Bunbury, from the sea shore), 24 May 1905, W. Michaelsen and R. Hartmeyer (Hamburg SW Australian Expedition).

**Remarks**

The date is given incorrectly as 24 July 1905 in Lager, 1911. Carlgren (1950) considered it likely that *Saccactis* Lager, 1911 was a synonym of *Oulactis* Milne-Edwards, 1851.

Genus *Stylobates* Dall, 1903

*Stylobates loisetteae* Fautin, 1987

*Stylobates loisetteae* Fautin, 1987: 2–6, figures 1–6.

**Material Examined**

*Holotype* number WAM 18–84 (f; wet) [new registration number: WAM Z 875], figures 3–4.

Locality: Station 55, Bunbury Bez., nordnordöstlich von Casuarina Point, Western Australia, Mieresstrand. (Station 55, NNE from Casuarina Point [33°18’S, 115°38’E], near Bunbury, from the sea shore), 24 May 1905, W. Michaelsen and R. Hartmeyer (Hamburg SW Australian Expedition).

**Remarks**

The locality was given incorrectly as Point Peron in Carlgren (1954). When alive, the column is a light grey-brown in colour with vertical rows of white spots and the tentacles and oral disc are mottled light brown and white. Part of one of the specimens is embedded in wax.
Family Stichodactylidae Andres, 1883
Genus Entacmaea Ehrenberg, 1834
Gyrostoma sulcatum Lager, 1911

Material Examined
Syntype number WAM 7121 (1; wet) [new registration number: WAM Z 887].
Locality: Station 45, Surf Point [26°07'S, 113°11'E], Shark Bay, Western Australia, at 0.5-3.5 m depth, 16 June 1905, W. Michaelsen and R. Hartmeyer (Hamburg SW Australian Expedition).

Remarks
Locality is given by Lager (1911) as "Stat. 25, Sharks Bay...". However, there are three labels with the specimen. One label clearly states Station 45, another has had Station 25 crossed out and Station 45 written in its place, and the final label has an ambiguous figure which could be read as either 25 or 45. This last label appears to be the original label.

Dunn (1981) reported this species as a synonym of Entacmaea quadricolor (Rueppell and Leuckart, 1828).

Order ZOANTHIDEA (?emend. Bourne 1900 pro Zoanthidae) Gray, 1840
Suborder BRACHNEMINA Haddon and Shackleton, 1891
Family Zoanthidae Gray, 1840
Genus Palythoa Lamouroux, 1816
Palythoa densa Carlgren, 1954

Material Examined
Syntypes number WAM 155-56 (1 colony; wet) [new registration number: WAM Z 880]; WAM 165-56 (7 pieces of colonies; wet) [new registration number: WAM Z 881].
Locality: Salmon Point [32°01'S, 115°31'E], Rottnest Island, Western Australia, on sides of pools on reef flat, 1951, L.M. Marsh.

Remarks
WAM 165-56 are part of the type series and are pieces collected from colonies 1-2 ft [0.3-0.6 m] in diameter. All colonies were bluish-grey in colour.

Carlgren (1954) had named this species after Mrs Loisette Marsh but had incorrectly spelt the word as marshi (ICZN 1985 Article 31 a).
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Zoanthus praelongus Carlgren, 1954


Material Examined

Syntypes number WAM 154–56 (12 pieces from more than 1 colony; wet) [new registration number: WAM Z 882].
Locality: West reefs on Garden Island [32°12'S, 115°40'E], Cape Peron [32°16'S, 115°41'E] and Rottnest Island [32°00'S, 115°30'E], Western Australia, amongst weed on the reef flat, in large clumps of hundreds of individuals, no collection date, L.M. Marsh.

Remarks
The locality in Carlgren (1954) is given incorrectly as "...Pt. Peron....". They are olive green in colour when alive.

Order SCLERACTINIA Bourne, 1900
Suborder ASTROCOENIINAE

Family Acroporidae Verrill, 1902

Genus Acropora Oken, 1815

Acropora abrolhosensis Veron, 1985


Material Examined

Holotype number WAM 160–84 (dry) [new registration number: WAM Z 899].
Locality: Rat Island [28°42'40"S, 113°47'00"E], Houtman Abrolhos Islands, Western Australia, at 3 m depth on an upper reef slope with consolidated, nearly horizontal substrate, October 1983, J.E.N. Veron.

Remarks
"An arborescent corallum 372 mm high" (Veron, 1985). The specimen is broken into two pieces.

Acropora indiana Wallace, 1994


Material Examined

Paratype (in part) number WAM 10–94 (1 piece; dry) [new registration number: WAM Z 902].
Locality: Scott Reef (14°00'S, 121°50'E), Timor Sea, NW Australia, at 18–25 m depth, 8 May 1992, R. Kelley.

Remarks
WAM specimen is broken into two pieces. The other part of the paratype is deposited at the Museum of Tropical Queensland, Townsville (MTQ G40782).

Acropora loisetteae Wallace, 1994


Material Examined

Paratype (in part) number WAM 11–94 (1 piece; dry) [new registration number: WAM Z 903].
Locality: Scott Reef (14°00'S, 121°50'E), Western Australia, at 8 m depth, 31 August 1993, E. Turak.

Remarks
Many branches are broken off the WAM specimen. The other part of the paratype is deposited at the Museum of Tropical Queensland, Townsville.

Acropora russelli Wallace, 1994


Material Examined

Paratype (in part) number WAM 2–95 (1 piece; dry) [new registration number: WAM Z 905].
Locality: Cartier Reef (12°33'S, 123°34'E), Rowley Shoals, Western Australia, 8 September 1993, E. Turak.

Remarks
The other part of the paratype is deposited at the Museum of Tropical Queensland, Townsville (MTQ G46447).

Acropora turaki Wallace, 1994


Material Examined

Paratype (in part) number WAM 9–94 (1 piece; dry) [new registration number: WAM Z 904].
Locality: Clerke Reef (17°22'S, 119°20'E), Rowley Shoals, Western Australia, 8 September 1993, E. Turak.

Remarks
The other part of the paratype is deposited at the Museum of Tropical Queensland, Townsville (MTQ G46447).
Genus *Astreopora* de Blainville, 1830

*Astreopora explanata* Veron, 1985


Material Examined

*Holotype* number WAM 161–84 (dry) [new registration number: WAM Z 906].

Locality: Beacon Island, Houtman Abrolhos Islands [28°S, 113°35'E], Western Australia, at 10 m depth on a lower reef slope with a partly consolidated, nearly horizontal substrate, March 1983, J.E.N. Veron.

Remarks

"A piece of a plate 168 mm across" (Veron, 1985).

Genus *Montipora* de Blainville, 1830

*Montipora capricornis* Veron, 1985

*Montipora capricornis* Veron, 1985: 149–150, figure 2.

Material Examined

*Holotype* number WAM 158–84 (dry) [new registration number: WAM Z 897].

Locality: Llewellyn Reef [23°42'S, 152°19'E], southern Great Barrier Reef, Queensland, at 4 m depth in an enclosed lagoon with turbid water and a soft bottom covered with rubble, 1980, J.E.N. Veron.

*Paratype* number WAM 159–84 (1; dry) [new registration number: WAM Z 898].

Locality: Fitzroy Reef [23°37'S, 152°10'E], southern Great Barrier Reef, Queensland, at 4 m depth in a lagoon with a substrate of sand and rubble, 1980, J.E.N. Veron.

Remarks

WAM 158–84 is "A plate-like corallum 179 mm maximum diameter" and WAM 159–84 is "A columnar corallum 139 mm high" (Veron, 1985).

Subgenus Caryophyllia Lamarck, 1801

*Caryophyllia* (Caryophyllia) stellula Cairns, 1998

*Caryophyllia* (Caryophyllia) stellula Cairns, 1998: 375–376, figure 2 a–c.

Material Examined

*Holotype* number WAM 301–88 (dry) [new registration number: WAM Z 606].

*Paratypes* number WAM 301–88 (11; dry) [new registration number: WAM Z 607].

Locality: Station 25, W of Rottnest Island [31°48'S, 114°58'E], Western Australia, dredged at 402.3 m depth, 16 March 1976, J.B. Hutchins and J. Scott on H.M.A.S. *Diamantina*.

Remarks

Four paratypes from WAM 301–88 were donated to the USNM (USNM 97817).

Genus *Oxysmilia* Duchassaing, 1870

*Oxysmilia circularis* Cairns 1998

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Material Examined

**Holotype** number WAM 102–83 (dry) [new registration number: WAM Z 612].
Location: Station SO2/82/16, 106 nautical miles NW of Port Hedland (18°41'S, 117°54'E to 18°41.7'S, 117°52.6'E), Western Australia, trawled at 200–204 m depth from limestone rocks and mud with a bottom temperature of 16.2°C, 2 April 1982, L.M. Marsh on F.V. Soela.

**Paratypes** number WAM 85–84 (4; dry) [new registration number: WAM Z 614].
Location: Station SO2/82/13A, 114 nautical miles N of Port Hedland (18°25'S, 118°22'E), Western Australia, dredged at 201 m depth from limestone rubble and grey mud, 2 April 1982, L.M. Marsh on F.V. Soela.

Remarks

Three paratypes from WAM 85–84 were donated to USNM (USNM 96990).

**Genus Rhizosmilia** Cairns, 1978

“**Rhizosmilia**" multipalifera Cairns, 1998

“**Rhizosmilia**" multipalifera Cairns, 1998: 386–388, figure 4 b, c, e, f.

Material Examined

**Holotype** number WAM 129–83 (dry) [new registration number: WAM Z 615].
Location: Station 41M, 35 km W of Jurien Bay (30°16.8'S, 114°39.6'E to 30°17.9'S, 114°39.9'E), Western Australia, dredged at 82.3 m depth, 19 February 1976, WAM Palaeontology Department on M.V. Sprightly.

**Paratypes** number WAM 129–83 (2; dry) [new registration number: WAM Z 616].
Location: Station 41M, 35 km W of Jurien Bay (30°16.8'S, 114°39.6'E to 30°17.9'S, 114°39.9'E), Western Australia, dredged at 82.3 m depth, 19 February 1976, WAM Palaeontology Department on M.V. Sprightly.

Remarks

The registration number for WAM 145–83 is given incorrectly as '148–83' in Cairns (1998).

**Family Turbinoliidae** Milne Edwards and Haime, 1848

**Genus Conocyathus** d'Orbigny, 1849

**Conocyathus gracilis** Cairns 1998

**Conocyathus gracilis** Cairns 1998: 388–390, figures 5 i, 6 a–d.

Material Examined

**Holotype** number WAM 31–85 (dry) [new registration number: WAM Z 624].
Location: Station 20M, 77 km SW of Dongara (29°21'S, 114°07'E to 29°21.5'S, 114°07.5'E), Western Australia, dredged at 146 m depth, 18 February 1976, WAM Palaeontology Department on M.V. Sprightly.
Location: NNW of Dampier (19°34'S, 116°08'E), Western Australia, dredged at 55 fathoms [110.6 m] depth, 19 August 1979, S.M. Slack-Smith on F.V. Soela.

Superfamily Flabellioidea Bourne, 1905
Family Flabellidae Bourne, 1905
Genus Flabellum Lesson, 1831
Subgenus Flabellum Lesson, 1831

Flabellum (Flabellum) folkesoni Cairns 1998
Flabellum (Flabellum) folkesoui Cairns 1998: 393–394, figure 6 e–i.

Material Examined
Holotype number WAM 173–83 (dry) [new registration number: WAM Z 625].
Paratypes numbers WAM 170–83 (1; dry) [new registration number: WAM Z 627]; WAM 260–93 (2; dry) [new registration number: WAM Z 628].

Location: Between Shark Bay [25°50'S, 114°10'E] and Onslow [21°38'S, 115°07'E], Western Australia, trawled, 1966, W. and W. Poole.

Paratype number WAM 212–92 (1; dry) [new registration number: WAM Z 631].

Location: Station S0001/0018 (19°32'S, 116°00'E to 19°31'S, 116°01'E), NNE of Montebello Islands, Western Australia, trawled at 144 m depth, 3 December 1979, S.M. Slack-Smith and L.M. Marsh on F.V. Soela.

Paratypes number WAM 98–83 (5; dry) [new registration number: WAM Z 629].

Location: Station SO2/82/09 (18°33'S, 118°22'E to 18°33'S, 118°20'E), 106 nautical miles NNW of Port Hedland, Western Australia, trawled at 150 m depth from sand or mud with a bottom temperature of 19.0°C, 28 March 1982, L.M. Marsh on F.V. Soela.

Paratype number WAM 609–88 (1; dry) [new registration number: WAM Z 630].

Location: Station SO4B/82/74 (18°43'S, 118°17'E to 18°44.2'S, 118°18.6'E), 120 nautical miles NNE of Port Hedland, Western Australia, trawled at 144 m depth from shell agglomerates, 19 August 1982, J. Marshall on F.V. Soela.

Paratype number WAM 62–83 (1; dry) [new registration number: WAM Z 632].

Location: Station SO5/82/47 (18°39.3'S, 118°57.0'E to 18°37.6'S, 118°54.2'E), 102 nautical miles NNE of Port Hedland, Western Australia, trawled at 128–130 m depth, 3 October 1982, L.M. Marsh and M. Bezant on F.V. Soela.

Paratype number WAM 12–96 (1; dry) [new registration number: WAM Z 632].

Remarks
The total number of paratypes for both WAM 170–83 and WAM 260–93 is given incorrectly as 23 specimens in Cairns (1998).

Three paratypes from WAM 98–83 were donated to USNM (USNM 97019), one specimen from WAM 27–96 was donated to USNM (USNM 96586) and three specimens from WAM 23–96 were donated to USNM (USNM 97020).

Genus Truncatoflabellum Cairns, 1989

Truncatoflabellum australiensis Cairns, 1998


Material Examined
Holotype number WAM 169–83 (dry) [new registration number: WAM Z 637].
Catalogue of recent Cnidaria types

Paratypes numbers WAM 171–83 (1; dry) [new registration number: WAM Z 657]; WAM 172–83 (2; dry) [new registration number: WAM Z 658]; WAM 442–96 (ex WAM 260–93) (2; dry) [new registration number: WAM Z 664].

Location: Between Shark Bay [25°50’S, 114°10’E] and Onslow [21°38’S, 115°07’E], Western Australia, trawled, 1966, W. and W. Poole.

Paratypes number WAM 59–83 (2; dry) [new registration number: WAM Z 638].

Location: Station SO5/82/37 (19°19.2’S, 116°46.3’E to 19°18.8’S, 116°44.8’E), 65 nautical miles N of Legendre Island, Western Australia, trawled at 132-144 m depth from sandy silt, 1 October 1982, L.M. Marsh and M. Bezant on F.V. Soela.

Paratypes number WAM 61–83 (1; dry) [new registration number: WAM Z 639].

Location: Station SO5/82/42 (18°39.3’S, 117°36.2’E to 18°38.6’S, 117°34.6’E), 98 nautical miles NW of Port Hedland, Western Australia, trawled at 140-164 m depth, 2 October 1982, L.M. Marsh and M. Bezant on F.V. Soela.

Paratypes numbers WAM 63–83 (1; dry) [new registration number: WAM Z 640]; WAM 66–83 (1; dry) [new registration number: WAM Z 641].

Location: Station SO5/82/47 (18°39.3’S, 117°36.2’E to 18°37.6’S, 116°54.2’E), 102 nautical miles NNE of Port Hedland, Western Australia, trawled at 128-130 m depth, 3 October 1982, L.M. Marsh and M. Bezant on F.V. Soela.

Paratypes number WAM 102–84 (2; dry) [new registration number: WAM Z 659].

Location: Station UMD 6927 (17°33.5’S, 117°33.0’E), W of Broome, Western Australia, at 92 m depth, 21 December 1969, K. Ozawa on Umitaka Maru Cruise.

Paratypes number WAM 134–83 (1; dry) [new registration number: WAM Z 642].

Location: Station 34M (29°07.2’S, 113°56.4’E to 29°08’S, 113°56.7’E), 97 km W of Dongara, Western Australia, dredged at 140.8 m depth, 19 February 1976, WAM Palaeontology Department on M.V. Sprightly.

Paratypes numbers WAM 224–93 (1; dry) [new registration number: WAM Z 660]; WAM 225–93 (1; dry) [new registration number: WAM Z 661].

Location: CSIRO station 208, cruise number DM 6/63, W of Bluff Point (27°40’S, 113°20’E), Western Australia, trawled at 71.5 fathoms [130 m] depth from sand and bryozoa, 10 October 1963, Chittleborough and Thomas.

Paratypes number WAM 24–96 (20; dry) [new registration number: WAM Z 665].

Location: Station LBS (18°42.8’S, 118°03.2’E to 18°39.6’S, 118°06.3’E), NE of Cape Lambert, Western Australia, sled at 150–160 m depth on limestone rubble and dead shells substrate, 18 August 1995, L.M. Marsh et al. on R.V. Lady Bastien.

Paratype number WAM 144–83 (1; dry) [new registration number: WAM Z 656].

Location: 20 miles [32.2 km] NW of Anchor Island, Onslow [21°38’S, 115°07’E], Western Australia, at 65 fathoms [118.9 m] depth, 17 June 1960, Western Australia Hawaiian Expedition.

Paratype number WAM 231–93 (1; dry) [new registration number: WAM Z 662].

Location: 10 miles [16 km] NNW of Anchor Island, Onslow [21°38’S, 115°07’E], Western Australia, at 65 fathoms [118.9 m] depth, 17 June 1960, Western Australia Hawaiian Expedition.

Paratypes number WAM 259–93 (6; dry) [new registration number: WAM Z 663].

Location: 14 miles [22.4 km] NNW of Anchor Island, Onslow [21°38’S, 115°07’E], Western Australia, at 65 fathoms [118.9 m] depth from gravel and mud, 17 June 1960, Western Australia Hawaiian Expedition.

Remarks

On the specimen label and in Cairns (1998) the cruise name is spelt incorrectly as Umitaka Maru for WAM 102–84.

Three paratypes from WAM 259–93 were donated to USNM (USNM 96652).

Cairns (1998) cites incorrectly the number of paratypes for WAM 24–96 as 19. He also states incorrectly that there were nine paratypes for WAM 144–83, 231– and 259–93 when in fact there were eight.

Truncatoflabellum macroeschara Cairns, 1998

Truncatoflabellum macroeschara Cairns, 1998: 401, figure 8 d, e, g–i.

Material Examined

Holotype number WAM 50–83 (dry) [new registration number: WAM Z 680].

Paratype number WAM 50–83 (1; dry) [new registration number: WAM Z 681].

Location: Station SO5/82/13 (19°52.3’S, 117°16.1’E to 19°52.9’S, 117°14.4’E), 43 nautical miles N of Cape Lambert, Western Australia, trawled at 56–58 m depth from sand, 27 September 1982, L.M. Marsh and M. Bezant on F.V. Soela.

Paratype number WAM 97–83 (1; dry) [new registration number: WAM Z 682].

Location: Station SO2/82/09 (18°33’S, 118°22’E to 18°33’S, 118°20’E), 106 nautical miles NNW of Port Hedland, Western Australia, trawled at 150 m...
depth from sand or mud with a bottom temperature of 19°C, 28 March 1982, L.M. Marsh on F.V. Soela.

Paratypes numbers WAM 77–84 (2; dry) [new registration number: WAM Z 683]; WAM 98–84 (2; dry) [new registration number: WAM Z 684].

Locality: Station SO2/82/13A (18°25'S, 118°22'E), 114 nautical miles N of Port Hedland, Western Australia, dredged at 201 m depth from limestone rubble and grey mud, 2 April 1982, L.M. Marsh on F.V. Soela.

Paralypes numbers WAM 77-84 (2; dry) [new registration number: WAM Z 683]; WAM 98-84 (2; dry) [new registration number: WAM Z 684].

Locality: Station SO2/82/13A (18°25'S, 118°22'E), 114 nautical miles N of Port Hedland, Western Australia, dredged at 201 m depth from limestone rubble and grey mud, 2 April 1982, L.M. Marsh on F.V. Soela.

Paratypes numbers WAM 37–96 (1; dry) [new registration number: WAM Z 694]; WAM 39–96 (2; dry) [new registration number: WAM Z 689].

Locality: Station LB6, 38 nautical miles S of Cunningham Island (18°09.5'S, 118°54.5'E to 18°07.1'S, 118°56.5'E), Imperieuse Reef, Western Australia, try net at 173–193 m depth on limestone rubble and dead shells substrate, 18 August 1995, L.M. Marsh et al. on R.V. Lady Basting.

Remarks

Cairns (1998) states incorrectly that there were two paratypes for WAM 77– and 98–84, when in fact there are two paratypes each; making the total number for both of these WAM numbers to be four.

One specimen from WAM 230–93 was donated to USNM (USNM 96661) and one specimen from WAM 39–96 was donated to USNM (USNM 96664).

Truncatoflabellum verotti Cairns, 1998

Truncatoflabellum veroni Cairns, 1998: 400, figures 7–g–i, 8–c.

Material Examined

Holotype number WAM 89–83 (dry) [new registration number: WAM Z 669].

Paratypes numbers WAM 89–83 (13; dry) [new registration number: WAM Z 670]; WAM 91–83 (3; dry) [new registration number: WAM Z 671].

Locality: Station SO2/82/54A (19°38'S, 115°07'E), Western Australia, at 65 fathoms [118.9 m] depth from mud and gravel, 17 June 1960, Western Australia Hawaiian Expedition.

Paratype number WAM 34–96 (1; dry) [new registration number: WAM Z 693].

Locality: Station LB5 (18°42.8'S, 117°35.5'E to 18°39.6'S, 117°46.3'E), NE of Cape Lambert, Western Australia, dredged at 150–160 m depth on limestone rubble and dead shells substrate, 16 August 1995, L.M. Marsh et al. on R.V. Lady Basting.

Paratypes number WAM 17–96 (3; dry) [new registration number: WAM Z 691].

Locality: Station LB5 (18°36.6'S, 118°07'E to 18°36.3'S, 118°08.5'E), 129 nautical miles NE of Cape Lambert, Western Australia, try net at 150–160 m depth on limestone rubble and dead shells substrate, 18 August 1995, L.M. Marsh et al. on R.V. Lady Basting.
Catalogue of recent Cnidaria types

46-49 m depth from sand, 27 September 1982, L.M. Marsh and M. Bezant on F.V. Soela.

Paratypes numbers WAM 47–83 (1; dry) [new registration number: WAM Z 674]; WAM 48–83 (1; dry) [new registration number: WAM Z 675].


Paratype number WAM 443–96 (1; dry) [new registration number: WAM Z 676].

Location: 64.4 km W of Cape Jaubert [18°57'S, 121°33'E], Western Australia, at 22 fathoms [40.2 m] depth, 13 October 1962, R.W. George on F.V. Dorothea.

Paratype number WAM 444–96 (1; dry) [new registration number: WAM Z 973].

Location: Station LB1b (20°09.98'S, 116°58.45'E to 20°09.07'S, 116°59.28'E), NNE of Legendre Island, Dampier Archipelago, Western Australia, sled at 45 m depth on sand, 17 August 1995, L.M. Marsh et al. on R.V. Lady Basten.

Remarks

Four paratypes from WAM 89–83 were donated to USNM (USNM 96655), one paratype from WAM 49–83 was donated to USNM (USNM 96658) and WAM 444–96 was donated to USNM (USNM 96660).

The specimen with registration number WAM 48–83 is broken in half.

Suborder FAVIINA

Family Merulinidae Verrill, 1866

Genus Hydnophora Fischer de Waldheim, 1807

Hydnophora pilosa Veron, 1985


Material Examined

Holotype number WAM 171–84 (dry) [new registration number: WAM Z 919].

Locality: Elizabeth Reef [29°58'S, 159°13'E], eastern Australia, at 6 m depth on a flat consolidated substrate exposed to moderate wave action, 1982, J.E.N. Veron.

Paratype number WAM 175–84 (1; dry) [new registration number: WAM Z 920].

Locality: Beacon Island, Houtman Abrolhos Islands [28°S, 113°35'E], Western Australia, at 28 m depth on a lower reef slope with a substrate of unconsolidated rubble, March 1983, J.E.N. Veron.

Paratype number WAM 176–84 (1; dry) [new registration number: WAM Z 921].

Locality: Legendre Island [20°23'S, 116°52'E], Dampier Archipelago, Western Australia, at 12 m depth on horizontal solid substrate in clear water, 1983, J.E.N. Veron.

Remarks

WAM 174–84 is "A complete colony with an encrusting base and a cluster of short branches. Maximum dimension 198 mm", WAM 175–84 is "A flat laminary plate 139 mm maximum dimension" and WAM 176–84 is "An arborescent corallum 129 mm high." (Veron, 1985).

The collection date is cited incorrectly as 1982 for WAM 175–84, in Veron (1985).

Family Mussidae Ortmann, 1890

Genus Australomussa Veron, 1985

Australomussa rowleyensis Veron, 1985

Australomussa rowleyensis Veron, 1985: 171–175, figures 23–25.

Material Examined

Holotype number WAM 171–84 (dry) [new registration number: WAM Z 907].

Locality: Legendre Island [20°23'S, 116°52'E], Dampier Archipelago, Western Australia, at 17 m depth at the base of a fringing reef with a nearly vertical slope, 1983, J.E.N. Veron.

Paratype number WAM 172–84 (1; dry) [new registration number: WAM Z 908].

Locality: Mermaid Reef [15°30'S, 119°00'E], Rowley Shoals, Western Australia, at 9 m depth in a protected, clear, reef lagoon with an undulating sand and rubble substrate, July 1982, J.E.N. Veron.

Paratype number WAM 173–84 (1; dry) [new registration number: WAM Z 909].

Locality: Phuket Peninsula, western Thailand, at 18 m depth on a substrate of steeply sloping rock and soft sediment in turbid water, 1984, J.E.N. Veron.

Remarks

WAM 171–84 is "A distorted, oval-shaped,
flattened whole corallum with a maximum dimension of 256 mm" and WAM 172–84 is "Part of a flat corallum. Maximum dimension 240 mm" (Veron, 1985).

The registration number for WAM 173–84 is written incorrectly as WAM 183–84 in Veron (1985).

Genus Lobophyllia de Blainville, 1830

Lobophyllia diminuta Veron, 1985


Material Examined

Holotype number WAM 167–84 (dry) [new registration number: WAM Z 913].

Locality: Northern Swain Reefs [22°00’S, 152°35’E], Queensland, at 2 m depth in a protected lagoonal area on a reef back margin, 1983, J.E.N. Veron.

Remarks

"A piece of branching corallum 154 mm maximum width" (Veron, 1985). The specimen is broken into three pieces.

Genus Symphyllia Milne-Edwards and Haime, 1848

Symphyllia wilsonii Veron, 1985


Material Examined

Holotype number WAM 168–84 (dry) [new registration number: WAM Z 910].

Locality: Rat Island [28°42’40”S, 113°47’00”E], Houtman Abrolhos Islands, Western Australia, at 8 m depth on a horizontal consolidated rock substrate exposed to moderate wave action, October 1983, J.E.N. Veron.

Paratype number WAM 169–84 (1; dry) [new registration number: WAM Z 911].

Locality: Port Denison [29°16’S, 114°55’E], Western Australia, at 9 m depth in a rocky crevice protected from strong wave action, 1982, J.E.N. Veron.

Paratype number WAM 170–84 (1; dry) [new registration number: WAM Z 912].

Locality: Port Denison [29°16’S, 114°55’E], Western Australia, at 12 m depth under a rock overhang protected from wave action, 1982, J.E.N. Veron.

Remarks

WAM 168–84 is a "... sub-circular flattened whole corallum with a maximum dimension of 114 mm." WAM 169–84 is "Part of a massive colony. Maximum dimension 139 mm." and WAM 170–84 is "Part of a massive colony. Maximum dimensions 142 mm." (Veron, 1985).

Suborder FUNGIINA

Family Agariciidae Gray, 1847

Genus Leptoseris Milne-Edwards and Haime, 1849

Leptoseris glabra Dineson, 1980


Material Examined

Holotype number WAM 390–77 (1; dry) [new registration number: WAM Z 900].

Locality: Goss Passage, Beacon Island, Houtman Abrolhos Islands [28°S, 113°35’E], Western Australia, at 31 m depth, 30 August 1977, B. R. Wilson.

Paratype number WAM 116–77 (1; dry) [new registration number: WAM Z 901].


Remarks

WAM 116–77 is broken into two pieces.

Family Fungiacyathidae Chevalier, 1987

Genus Fungiacyathus Sars, 1872

Subgenus Fungiacyathus Sars, 1872

Fungiacyathus (Fungiacyathus) multicarinatus Cairns, 1998

Fungiacyathus (Fungiacyathus) multicarinatus Cairns, 1998: 370, figure 1 a–c.

Material Examined

Holotype number WAM 547–84 (dry) [new registration number: WAM Z 605].

Location: Station SOOl/84/054, WNW Lacepede Archipelago (15°51.2’S, 120°44.3’E to 15°49.3’S, 120°45.3’E), Western Australia, trawled at 348–350 m from a soft bottom, 10 February 1984, S.M. Slack-Smith on F.V. Soela.
Catalogue of recent Cnidaria types

Family Poritidae Gray, 1842

Genus *Alveopora* de Blainville, 1830

*Alveopora gigas* Veron, 1985


Material Examined

*Holotype* number WAM 166-84 (dry) [new registration number: WAM Z 918].

Locality: Near Rat Island [28°42'40"S, 113°47'00"E], Easter Group, Houtman Abrolhos Islands, Western Australia, at 12 m depth on a very protected reef slope with unconsolidated substrate, October 1983, J.E.N. Veron.

Remarks

"A column end 150 mm long and 84 mm thick" (Veron, 1985). Veron (1985) states the date of collection as ‘1982’.

Genus *Goniopora* de Blainville, 1830

*Goniopora pendulus* Veron, 1985


Material Examined

*Holotype* number WAM 164-84 (dry) [new registration number: WAM Z 916].

Locality: Near Rat Island [28°42'40"S, 113°47'00"E], Easter Group, Houtman Abrolhos Islands, Western Australia, at 8 m depth on a sloping reef with unconsolidated substrate, protected from strong wave action, October 1983, J.E.N. Veron.

Remarks

WAM 164-84 is a "...148 mm long piece of a massive corallum" and WAM 165-84 is a "...132 mm long piece of a massive corallum" (Veron, 1985).

Genus *Porites* Link, 1807

*Porites* (*Porites*) *heronensis* Veron, 1985


Material Examined

*Holotype* number WAM 162-84 (dry) [new registration number: WAM Z 914].

Locality: Heron Island [23°27'S, 151°55'E], Queensland, at 2 m depth on an upper reef slope exposed to moderate wave action, 1982, J.E.N. Veron.

Remarks

"An encrusting incomplete corallum 126 mm diameter" (Veron, 1985).

*Porites* (*Porites*) *myrmidonensis* Veron, 1985


Material Examined

*Holotype* number WAM 163-84 (dry) [new registration number: WAM Z 915].


Remarks

"An encrusting corallum 126 mm diameter" (Veron, 1985).

Family Siderastreidae Vaughan and Wells, 1943

Genus *Coscinaraea* Edwards and Haime, 1848

*Coscinaraea marshae* Wells, 1962


Material Examined

*Holotype* number WAM 104-58 (dry) [new registration number: WAM Z 889].

Locality: Point Clune, Rottnest Island [32°00'S, 115°30'E], Western Australia, at 10 feet [3 m] depth, no collection date, E.P. Hodgkin.

Paratypes numbers WAM 103-58 (1; dry) [new registration number: WAM Z 891], plate 18 figures 1-2.

Locality: Cathedral Rocks, Rottnest Island [32°00'S, 115°30'E], Western Australia, March 1956, E.P. Hodgkin.
Paratype number WAM 101-58 (1; dry) [new registration number: WAM Z 893] plate 17, figure 4.

Locality: Point Clune, Rottnest Island [32°00’S, 115°30’E], Western Australia, at 10 feet [3 m] depth, no collection date, E.P. Hodgkin.

Paratype number WAM 100-58 (1; dry) [new registration number: WAM Z 894].

Locality: Woodman Point [32°08’S, 115°44’E], near Fremantle, Western Australia, 1957, E. Carr.

Paratype number WAM 52-59 (1; dry) [new registration number: WAM Z 895].

Locality: Eagle Bay [33°33’S, 115°06’E], Cape Naturaliste, Western Australia, at 25 feet [7.5 m] depth from a crevice in a rocky ledge, 1958, B.R. Wilson and L.M. Marsh.

Paratype number WAM 59-59 (1; dry) [new registration number: WAM Z 896], plate 18 figure 3.

Locality: 1.5 miles (2 km) north of Dunsborough [33°36’S, 115°06’E], Geographe Bay, Western Australia, at 30 feet [9 m] in a rock crevice, 26 December 1958, B.R. Wilson and L.M. Marsh.

Remarks

Wells (1962) misquotes WAM 52-59 as ‘WAM 52-29’.

Colonies numbers WAM 101-58 and WAM 104-58 were brown in colour when alive. The colony of WAM 52-59 was yellow-brown in colour when alive.

The specimen of WAM 100-58 is broken into two pieces. Specimen WAM 59-59 is part of a colony only. Specimen WAM Z 890 was the unregistered paratype described in Wells (1962).

In Wells (1962), under the subheading ‘Occurrence’ (page 241), WAM 103-58 is written incorrectly as ‘WAM 103-28’.

Specimen numbers WAM 100-58, WAM 102-58 and WAM 52-59 have been re-identified as Coscinaraea mcneillii Wells, 1962 by Veron and Marsh (1988).

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REFERENCES


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A new breeding record for the Lesser Crested Tern *Sterna bengalensis* in the Lowendal Islands, northwestern Australia

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To date the only records of the Lesser Crested Tern, *Sterna bengalensis* Lesson, breeding in Western Australia have been on Adele Island (Serventy et al. 1971), Ashmore Reef, and on Lacepede, Bedout and Y Islands (Storr 1984 and Burbidge et al. 1996). This paper reports a new breeding location for this species, on Beacon Island, within the Lowendal Group of islands (20°39′52″S, 115°34′44″E). Lesser Crested Terns were recorded nesting in conjunction with Crested Terns, *Sterna bergii* Lichtenstein, on two separate occasions in 1997. On 8 March 1997 both Crested and Lesser Crested Terns were incubating eggs within a mixed colony of approximately 1000 nests, on Beacon Island. Lesser Crested Terns made up approximately 15% of the total number of pairs present. Nesting was estimated as having commenced within the previous five days. By 15 March 1997, the number of nests had increased to approximately 5000, with approximately the same proportion of Lesser Crested Tern nests.

On 3 May 1997 approximately 500 nests contained eggs and hatchlings after a second wave of laying, with thousands of 3–14 day old chicks creching on the beach. Lesser Crested Terns made up approximately 10% of chicks in the creche and less than 5% of those adults still nesting. The breeding colony was spread along a rocky cliff ledge and low dunes covered by patches of *Spinifex longifolius* R. Br., making access to most parts of the colony difficult without undue disturbance. As a result, estimates of the numbers of breeding terns was based upon counts in those areas easily seen, then extrapolated to areas that could not be seen. However, the numbers of departing and arriving adults indicated similar proportions of the two Crested Tern species.

The breeding colony of Lesser Crested Terns on Beacon Island was estimated to contain approximately 700 pairs, and that of Crested Terns to contain approximately 4500 pairs. Lesser Crested Tern breeding populations which have been estimated elsewhere in Western Australia are 0–500 pairs on Ashmore Reef (east), 2–16 on Bedout Island, and 500–1000 on Lacepede Island (west) (Burbidge and Fuller 1996). No estimates of the breeding populations on Adele and Y Islands have been published.

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REFERENCES


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Guide to Authors

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Reviews, observations and results of research into all branches of natural science and human studies will be considered for publication. However, emphasis is placed on studies pertaining to Western Australia. Longer papers will be considered for publication as a Supplement to the Records of the Western Australian Museum. Short communications should not normally exceed three typed pages and this category of paper is intended to accommodate observations, results or new records of significance, that otherwise might not get into the literature, or for which there is a particular urgency for publication. All material must be original and not have been published elsewhere.

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Cover: Metanocticola christmasensis Roth – a new species of cave-dwelling cockroach described in this issue from Christmas Island. Illustration by Jill Ruse.

Copepods from ground waters of Western Australia, IV. Cyclopids from basin and craton aquifers (Crustacea: Copepoda: Cyclopidae)

P. De Laurentiis¹, G.L. Pesce¹ and W.F. Humphreys²
¹Dipartimento di Scienze Ambientali, University of L’Aquila, Via Vetoio, I-67100 L’Aquila, Italy
²Western Australian Museum, Francis Street, Perth, Western Australia 6000, Australia

Abstract - Halicyclops rochaei sp. nov. is described from a near-coastal aquifer in the Robe River basin. Diacyclops rediae sp. nov. and Diacyclops cinslei sp. nov. are described from the Millstream aquifer in the western Fortescue Valley on the Pilbara craton. Records with large range extensions are given for Paracyclops fimbriatus (Fischer, 1853), Diacyclops humphreysi Pesce and De Laurentiis, 1996, Microcyclops varicus (G.O. Sars, 1863), Metacyclops mortoni Pesce, De Laurentiis and Humphreys, 1996 and Mesocyclops brooksi Pesce, De Laurentiis and Humphreys, 1996. The description of D. humphreysi is amplified. Halicyclops rochaei sp. nov. belongs to a Tethyan group of species and is similar to Halicyclops sp. nov. Rocha et al. from the Yucatan Peninsula, Mexico. As such, it accords with the biogeographic affinities of non-copepod elements of the fauna.

INTRODUCTION

Arid northwestern Australia is proving to contain a diverse subterranean fauna in both terrestrial (Humphreys 1993c) and aquatic systems (Humphreys 1993a; papers in Humphreys 1993b). The stygofauna in particular contains many remarkable disjunct lineages in both anchialine (e.g. Yager and Humphreys 1996) and freshwater aquifers (Poore and Humphreys 1998), the existence, extent and affinities of which are only just being explored (Humphreys, in press a, in press b).

Cyclopoid copepods recently collected from the near-coastal areas of northwestern Australia have included the genera Metacyclops Kiefer, 1927 sensu Lindberg, 1961, Mesocyclops G.O. Sars, 1914, Microcyclops Claus, 1893, Apocyclops Lindberg, 1942, Halicyclops Norman, 1903 and Diacyclops Kiefer, 1927 (Pesce, De Laurentiis and Humphreys 1996a, 1996b; Pesce and De Laurentiis 1996). These studies greatly extended the range of some species and revealed a number of new species, some of which are restricted to groundwaters in this arid region.

The present paper examines material from the Pilbara craton (Millstream), a region of prolonged stability and not inundated by the sea since the Proterozoic (Hocking et al. 1987), as well as collections made on the coastal plains of Mesozoic age or younger (Yarraloola and Mardie Stations) that fringe the craton. Some collections from groundwaters in the Perth Basin are included.

HABITAT AND ASSOCIATED FAUNA

The area is arid with the annual evaporation exceeding the low annual rainfall (c. 350 mm) by about an order of magnitude, and is characterised by very high summer temperatures. The detailed environment is unknown, but water chemistry data are available for a number of sites.

Millstream - The Millstream aquifer, in Tertiary valley fills of palaeodrainage channels on the Pilbara craton, is in a karstic groundwater calcrete and freshwater (TDS 864 mg L⁻¹; s.e. 128.8, n=6—raw data from pump tests in Barnett and Commander 1985) with a pH of 7.4±0.09. The characteristics of the Millstream aquifer and its geological context have been discussed at length by Poore and Humphreys (1998), together with the potential great age of the associated fauna (see also Humphreys 1993a, in press b). Forty-six locations were sampled in the Millstream aquifer, of which 20 yielded fauna of some type (16 piezometers, three wells, one water bore).

The associated fauna in the aquifer includes a new genus of Spelaeogriphacea, the first record of the order in Australasia (Poore and Humphreys 1998), as well as other elements of a clearly Gondwanan fauna, including inter alia a genus of water mites previously known only from India (Harvey 1998), syncarids (Bathynellacea), phreatoicid isopods, phreodrilid oligochaetes, and also hydrobioid gastropods, ostracods and crangonyctoid amphipods.

Mardie and Yarraloola Stations, Carnarvon Basin - The aquifers are in gravel fans resulting from the discharges through water gaps respectively of the Fortescue and Robe Rivers from the Pilbara craton onto the coastal plain of the Carnarvon Basin (Commander 1994a, 1994b). They lie unconformably on Precambrian banded iron...
formation (Proterozoic schist in the case of the Robe Valley) and basalt, Cretaceous conglomerate and siltstone, and on Tertiary pisolite and limestone (ibid.). Groundwater salinity ranges from 345 mg L\(^{-1}\) (TDS) close to the river to 1200 mg L\(^{-1}\) near the tidal flats where there is a saltwater interface (ibid.). Samples were taken from 35 bores and pastoral wells in two groundwater assessment borefields. The fauna of these aquifers includes elements of the Tethyan fauna found on the Cape Range peninsula and Barrow Island (Humphreys 1993a, in press a) including atyid shrimp, cirolanid isopods and thermostaenaceans, as well as diverse amphipods (Paramelitidae, Bogidiellidae: J. Bradbury, pers. comm. 1997; Bradbury and Williams 1997), ostracods, bathyneillid syncarids, halacarid mites, hydrobioid gastropods and microturbellarians.

Perth Basin - Samples were taken from a number of groundwater monitoring bores in unconfined aquifers in Quaternary-Late Tertiary deposits of the Perth Basin (Davidson 1995), north of the Swan River and bordering the Yilgarn craton. The water was essentially fresh and mostly distant from surface drainage channels. The general fauna included ostracods and bathyneillid syncarids, harpacticoid copepods, oligochaetes, microturbellaria and nematodes. Outflows from the water mounds to the west of the sample area support a rootmat community that is rich in fauna in shallow cave environments (Jasinska, et al. 1996). All the copepods mentioned herein came from a restricted area of the Gnangara Mound (South) in an area of upward leakage from the Mirrabooka sandstone aquifer, which is of Cretaceous age, with salinity less than 500 mg L\(^{-1}\) TDS and the only associated fauna comprised ostracods and oligochaetes.

Yule and De Grey Rivers - respectively in the Pilbara Province (Whincup 1967) and the Canning Basin (Davidson 1975). There samples were taken from unused bores in the current freshwater production borefield (Water Corporation) located in these sand aquifers. Samples were taken at 18 locations (13 in the Yule) and the associated fauna included ostracods, amphipods (Melitidae) and bathynellid syncarids.

Port Hedland and Cossack - A single sample was taken at each site from early historical wells. Associated fauna includes ostracods.

**MATERIAL AND METHODS**

In October 1996 a brief reconnaissance survey of some groundwaters was conducted in northwestern Australia. Groundwater was sampled with haul nets (350 µm mesh size) predominantly from groundwater monitoring bores — some samples were taken from pastoral wells and from river gravels by the Karaman-Chappuis method — in aquifers along the Western Fortescue Plain (Millstream) and the lower Fortescue (Mardie Station) and Robe Rivers (Yarraloola Station: Map 1). Minor sampling was undertaken at Cossack, Port Hedland, and aquifers in the De Grey and Yule Rivers. Some samples from the Perth Basin were also examined (Map 1).

All samples were sorted while alive under a dissecting microscope, preserved in 70% alcohol and assigned a field number (BES number).

Permanent mounts were made in commercial polyvinyl-lactophenol medium. Dissected specimens were drawn at magnifications of 400x and 1000x, the latter using an oil immersion lens and “camera lucida” mounted on a Leitz Laborlux D phase-contrast microscope. Type material is deposited in the Western Australian Museum (WAM).

Terminology applied to body and appendages is according to Huys and Boxshall (1991).
Cyclopids from basin and craton aquifers

SYSTEMATICS

Family Cyclopidae Burmeister, 1834 emend. Dana, 1846

Subfamily Halicyclopinae Kiefer, 1927

Genus Halicyclops Norman, 1903

Halicyclops rochai sp. nov.

Figures 1-21

Material Examined

Holotype

♀ (WAM C 24171), bore 4A, Yarraloola Station, Robe R., Western Australia, Australia (BES 4061), 21°34'S, 115°51'E, 24 October 1996, W.F. Humphreys.

Paratypes


Description

Female

Length of holotype, excluding caudal setae, 538 μm; paratype 530 and 563 μm. Rostrum (Figure 10) subtriangular in frontal view, with 6 sensilla. First pedigerous somite fused with the cephalosome forming cephalothorax.

Genital double-somite (Figure 11) wider than long. Seminal receptacle as in Figure 11. Hyaline fringes of urosomites crenulate dorsally and ventrally.

Anal somite (Figure 14) bearing row of spinules along posterior margin and a pair of sensilla. Anal operculum not well defined.

Caudal rami (Figure 13) about as long as wide, with 6 setae. Posterolateral seta slightly shorter than terminal accessory seta; dorsal seta very long, more than twice longer than terminal accessory seta; setation of the outer and inner terminal setae as in Figure 15.

Antennule (Figure 2) 6-segmented. Number of setation elements as follows: 5, 12, 5 + 1 spine, 6 + aesthetasc, 2, 10 + aesthetasc. Most setae sparsely plumose. Proximal segment with a row of small spinules at base of ventral surface.

Antenna (Figure 6): 3-segmented, excluding reduced coxa; basis with 2 inner plumose setae and one outer seta (exopod) overreaching the tip of the first endopodal segment; endopod segment 1 with 1 seta, segment 2 with 5 inner setae, 7 apical setae, and 2 rows of cilia on outer margin.

Labrum (Figure 9) with laterally serrate distal margin and row of 14 rounded teeth midway along margin, the outer ones stouter; paired transverse rows of spinules on anterior surface, rows of smaller spinules on posterior surface.

Paragnaths (Figure 8) are simple lobes bearing patches of fine setules and spinules, and 3 well developed pectinate setae.

Mandible (Figure 1) with coxal gnathobase armed with 8 sharp teeth, 1 pectinated element and 2 dorsal plumose setae; transverse row of 3 long spinules implanted subdistally on cutting blade. Palp represented by 2 unequal setae implanted directly on coxa.

Maxillule (Figure 3) consisting of praecoxa and 2-segmented palp. Praecoxal arthrite armed with 4 spines, and 7 elements on inner surface. Palp comprising coxobasis with 1 spinulate spine and 2 setae distally and 1 seta (representing exopod) on outer margin, and 1-segmented endopod bearing 3 long setae.

Maxilla (Figure 4) 4-segmented; praecoxa with single distal endite armed with 2 elements; proximal coxal endite represented by a single seta; distal coxal endite armed with 1 spine fusing to endite and ornamented with 4 strong spinules, and 1 spine. Basis with endite bearing 2 stout elements and 1 seta. Endopod 1-segmented, bearing 3 stout elements plus 2 setae.

Maxillipede (Figure 5) 2-segmented; proximal segment bearing 3 setae, terminal segment two inner modified setae, 1 distal, stout modified seta and 2 subdistal setae.

Legs 1-4 armed as follows (Roman numerals representing spines; Arabic numerals setae):

<table>
<thead>
<tr>
<th>Leg 1</th>
<th>Coxa</th>
<th>Basis</th>
<th>Exopod</th>
<th>Endopod</th>
</tr>
</thead>
<tbody>
<tr>
<td>leg1</td>
<td>0-1</td>
<td>1-1</td>
<td>1-1</td>
<td>I-I+1</td>
</tr>
<tr>
<td>leg2</td>
<td>0-1</td>
<td>1-0</td>
<td>1-1</td>
<td>I-I+1</td>
</tr>
<tr>
<td>leg3</td>
<td>0-1</td>
<td>1-0</td>
<td>1-1</td>
<td>I-I+1</td>
</tr>
<tr>
<td>leg4</td>
<td>0-1</td>
<td>1-0</td>
<td>1-1</td>
<td>I-I+1</td>
</tr>
</tbody>
</table>

Spine at inner corner of leg 1 basis (Figure 17) reaching about mid-length of endopod 2.

Endopod 3 of legs 2 and 3 (Figure 19) with proximalmost seta stiff, plumose basally and serrate distally.

Leg 4 endopod (Figure 18) about 2 times longer than wide, inner apical spine shorter than segment; both inner setae spiniform, serrate distally and plumose basally.

Leg 5 exopod (Figure 12) slightly longer than wide, armed with 3 spines and 1 seta, all spines shorter than segment.

Male

Body length ranging from 458 to 556 μm (n=4). Caudal rami (Figure 13) about as long as wide.
Figures 1-10 *Halicyclops rochii* sp. nov., 2, 6, 8, 9 (holotype), 1, 3-5, 7, 10 (paratype): 1, mandible; 2, ♀ antennule; 3, maxillula; 4, maxilla; 5, maxilliped; 6, antenna; 7, ♂ antennule; 8, paragnaths; 9, labrum; 10, rostrum.
Figures 11-16  Halicyclops rocfm. nov., 11, 14, 15 (holotype), 12, 13, 16 (paratype): 11, ♀ abdomen (ventral view), 12, ♀ leg 5, 13, ♂ abdomen (ventral view), 14, furcal rami (dorsal view); 15, furcal terminal setae, 16, ♂ leg 5.
Antennule (Figure 7) 14-segmented. Setation as follows: 8 + 3 aesthetascs, 4, 5 + aesthetasc, 3, 1, 2, 1 + spine + aesthetasc, 2, 2 + aesthetasc, 2 spines, 1 + spine + aesthetasc, 1 spine, 1 + aesthetasc, 9 + 2 aesthetascs.

Leg 5 exopod (Figure 16) slightly longer than wide, with 2 outer spines, 1 apical seta, 1 inner serrate spine — slightly longer than outer spines — and 2 inner setae.

Leg 6 (Figure 13) represented by 2 setae and spine.
The male is identical to the female in all other respects. Only in one specimen (BES 4071) (Figures 20, 21), endopod 3 of legs 2 and 3 bears 3 inner normal setae and 3 spiniform setae, respectively.

Affinities

*Halicydops rochai* fits within a Tethyan group of species ("caridophilus-group") characterized by the presence of 2 inner setae on the leg 5 exopod in the males.

At present, besides the new species, the group includes *H. caridophilus* Humes, 1974, from Borneo, *H. tetracanthus* Rocha, 1995, from Belize, and *Halicydops* sp. nov., a new species from a cenote the Yucatan Peninsula, Mexico (Rocha et al., in press).

*Halicydops rochai* differs from *H. caridophilus* by numerous characteristics, such as the mandibular palp bearing 2 setae (versus 1 seta), the different armature of the labrum, maxilliped and furcal rami, the different length of the spine on both the endopod and exopod 3 of leg 4. From *H. tetracanthus* it mostly differs by the number of spines on terminal endopodal segment of legs 2-3 (3 in *H. rochai*, 4 in *H. tetracanthus*) and by the armature of intercoxal sclerites of the legs 2 to 4 (naked in *H. rochai*, with rows of spinules on the free margin in *H. tetracanthus*), and by other characters, viz. the length of the genital double-somite (about as long as wide in *H. rochai*, longer than wide in *H. tetracanthus*), the armature of female leg 6, consisting of 1 short spine and 1 seta in *H. rochai*, 2 short spines and 1 seta in *H. tetracanthus*, and the ornamentation of the inner terminal furcal setae.

The new species is very close to *Halicydops* sp. nov. Rocha et al. with which it shares, besides other characteristics, some peculiar features, such as the length of the dorsal and the terminal accessory setae.

Material Examined

**Australia:** Western Australia: 1 ♀ (WAM C 24176), groundwater monitoring bore (GWMW) AM 33A, Perth Basin (BES 4541), 31°50'S, 115°47'E, 6 March 1997, W.F. Humphreys and J. Waldock; 1 ♂ (WAM C 24177), same data as above, (BES 4544), same data as above; 4 ♀ (WAM C 24178), GWMW GM3, Perth Basin (BES 4546), 31°54'S, 115°49'E, same data as above; 1 ♀ (WAM C 24179), GWMW GM27, Perth Basin, (BES 4547), 31°54'S, 115°49'E, same data as above; 1 ♀ (WAM C 24180), GWMW GM28, Perth Basin, (BES 4549), 31°54'S, 115°50'E, same data as above; 1 ♀ (WAM C 24181), GWMW GM15, Perth Basin, (BES 4551), 31°52'S, 115°50'E, same data as above; 1 ♀ (WAM C 24182), GWMW GM34, Perth Basin, (BES 4558), 31°52'S, 115°50'E, same data as above.

Remarks

*Paracyclops fimbriatus* is widely distributed throughout the Australian continent, inhabiting both surface and ground fresh waters. According to some authors (Dussart 1969; Monchenko 1974; Plesa 1981) this species is characterized by a great variability that could include, as synonyms, the following taxa: *P. fimbriatus f. minutula* Kiefer, 1929; *P. finitimus* Chappuis, 1929; *P. fimbriatus f. brumetarium* Herbst, 1959 and *P. fimbriatus chiltoni* (Thomson, 1882).
Description

**Female**

Length of holotype, excluding antennule and caudal setae, 486 μm; range of length of paratypes 428–465 μm.

Genital double somite (Figure 35) wider than long, ornamented with 2 sensilla on dorsal surface and bearing copulatory pore mid-ventrally. Hyaline frills of urosomites weekly crenulate both dorsally and ventrally. Anal somite (Figure 35) bearing pair of dorsal sensilla and operculum with smooth posterior margin.

Caudal rami (Figure 35) 1.70–1.96 longer than wide, in ventral view. Only 6 setae present; seta I absent; seta II located on dorsal surface, about 75% of distance along ramus; seta VI about 2.4 times longer than ramus. Group of cilia present on dorsal inner surface, about 30% of distance along ramus.

Antennula (Figure 22) 4-segmented, excluding unarmed coxa; basis bearing 2 spinulose setae around inner distal angle and ornamented with one spinule row along ventral margin, and 4 spinule rows on the dorsal side; exopodal seta absent. Endopod 3-segmented; first segment with inner spines of distance along ramus; second segment with 6 setae (2 along the inner margin, 4 along inner part of distal margin); third segment armed with 7 setae.

Labrum (Figure 30), posterior part convex and bearing 6–7 stout teeth, lateral corners strongly denticulate; remaining ornamentation as in Figure 30. Paragnaths (Figure 32) consisting of paired lobes, ornamented with usual rows of fine setules and 3 setulose spines, one stout spiniform process and a row of small spines along the inner margin. Mandible (Figure 28) with well developed coxa with gnathobase; gnathobasic blades mostly simple, innermost dorsal surface with row of spines, palp reduced, bearing 3 setae, one very short.

**Material Examined**

**Holotype**

♀ (WAM C 24196), bore P1, Millstream aquifer, Western Australia, Australia (BES 4005), 21°34'S, 116°58'E, 19 October 1996, W.F. Humphreys.

**Paratypes**

Australia: Western Australia: 1 ♀ and 1 ♂ (WAM C 24197), same data as holotype; 1 juv. (WAM C 24198), bore 7A, Millstream aquifer (BES 4002), 21°35'S, 117°01'E, 16 October 1996, W.F. Humphreys; 2 ♀, 1 ♂ (WAM C 24199), bore 7C, Millstream aquifer (BES 3968), 21°38'S, 117°01'E, 16 October 1996, W.F. Humphreys.

Remarks

The new material which we examined of this species, as well as the re-examination of the holotype, revealed some new or previously overlooked characteristics regarding the labrum, paragnaths, basipodite of the antenna, male leg 6, and bearing copulatory pore mid-ventrally. Hyaline frills of urosomites weekly crenulate both dorsally and ventrally. Anal somite (Figure 35) bearing pair of dorsal sensilla and operculum with smooth posterior margin.

Caudal rami (Figure 35) 1.70–1.96 longer than wide, in ventral view. Only 6 setae present; seta I absent; seta II located on dorsal surface, about 75% of distance along ramus; seta VI about 2.4 times longer than ramus. Group of cilia present on dorsal inner surface, about 30% of distance along ramus.

Antennula (Figure 22) 4-segmented, excluding unarmed coxa; basis bearing 2 spinulose setae around inner distal angle and ornamented with one spinule row along ventral margin, and 4 spinule rows on the dorsal side; exopodal seta absent. Endopod 3-segmented; first segment with inner spines of distance along ramus; second segment with 6 setae (2 along the inner margin, 4 along inner part of distal margin); third segment armed with 7 setae.

Labrum (Figure 30), posterior part convex and bearing 6–7 stout teeth, lateral corners strongly denticulate; remaining ornamentation as in Figure 30. Paragnaths (Figure 32) consisting of paired lobes, ornamented with usual rows of fine setules and 3 setulose spines, one stout spiniform process and a row of small spines along the inner margin. Mandible (Figure 28) with well developed coxa with gnathobase; gnathobasic blades mostly simple, innermost dorsal surface with row of spines, palp reduced, bearing 3 setae, one very short.

**Material Examined**

**Holotype**

♀ (WAM C 24196), bore P1, Millstream aquifer, Western Australia, Australia (BES 4005), 21°34'S, 116°58'E, 19 October 1996, W.F. Humphreys.
Figures 33–40  *Dreucylops reidae* sp. nov., 34–36, 37, 39 (holotype), 33, 38, 40 (paratype): 33, leg 2; 34, leg 3; 35, ♀ abdomen (ventral view); 36, leg 4; 37, leg 1; 38, ♂ leg 5; 39, ♀ leg 5; 40, ♂ abdomen (ventral view).
Maxillule (Figure 26), praecoxa bearing reduced 2-segmented palp (Figure 29). Praecoal endite armed with 6 spinulose setae and 3 spines fused to segment. Proximal segment palp bearing 3 inner margin setae (one stout and spinulose) and an outer seta representing exopod. Distal segment of palp, representing endopod, armed with 3 plumose setae.

Maxilla (Figure 25) comprising partially fused praecoxa and coxa, basis and 2-segmented endopod. Praecoxa bearing one endite armed with 2 plumose setae, coxa with 2 endites, the proximal one bearing one plumose seta, the distal one bearing one seta and one bifid setulose spine; basis with a well-developed claw and 2 setae. First endopodal segment bearing 2 spinulose setae, second with 3 setae.

Maxilliped (Figure 24) 4-segmented, comprising syncoxa, basis and 2-segmented endopod. Syncoxa bearing 2 inner margin spinulose setae representing 2 vestigial endites, and rows of spinules along the outer margin. Basis armed with 2 inner spinulose setae and rows of spinules along the inner and outer margins. First endopodal segment bearing a single plumose seta and spinules around its base. Second endopodal segment with a long spinulose seta and two shorter, naked setae.

Swimming legs 1 to 4, 3-segmented (Figures 34, 35, 36, 37). Intercoxal sclerites with rows of small spinules. Praecoxa represented by triangular sclerite, armed with row of small spinules. Coxa armed with inner plumose seta and ornamented with rows of small anterior and posterior spinules. Basis of leg 1 (Figure 37) with long outer seta, inner spine well overreaching the second endopodal segment, and ornamented with spine row between rami. Outer spines on the exopods of legs 1-2 ornamented as in figs 37 and 33. Endopod 3 of leg 4 (Figure 36) about 1.7 times longer than wide, outer spine longer than segment and about twice longer than the innermost.

Spine and seta formula as follows:
- coxa basis endopod exopod
  - leg1 0-1 1-1 0-1; 0-1; 1, 1+1,2 I-1; 1-I; II, I, I, 3
  - leg2 0-1 1-0 0-0; 0-1; 1, 1+1,2 I-1; 1-I; III, I, I, 3
  - leg3 0-1 1-0 0-1; 0-2; 1, 1+1,2 I-1; 1-I; III, I, I, 3
  - leg4 0-1 0-0 0-0; 0-1; II, I, I, 1-1; 1, I; I-I; III, I, I, 3

Fifth leg (Figure 39) 2-segmented; protopodal segment narrow, bearing outer plumose seta; exopodal segment about twice as long as wide, bearing 1 plumose seta and one setiform spine distally, both longer than segment.

Sixth leg (Figure 35) bearing 2 spines and one seta.

Male

Body (Figure 40) length from 319 to 375 μm. Antennule (Figures 27, 31) digeniculate, 16-segmented. Setation as follows: 8+3 aesthetascs, 4, 2, 2+2 aesthetasc, 2, 2, 2, 2, 1+spine+aesthetasc, 2, 1+spine, 2 spines, spine+aesthetasc+striated element, 1, 2 striated element, 11.

All other appendages as in female except for sixth leg (Figure 40), forming opercular plates bearing one plumose spine and 2 setae.

Affinities

*Diacyclops reidae* is discussed together with *Diacyclops einslei*.

Etymology

The species is dedicated to J.W. Reid, distinguished copepodologist, in recognition of her valuable contributions to knowledge of the cyclopine copepods.

*Diacyclops einslei* sp. nov.

Figures 41-50

Material Examined

 holotype
♀ (WAM C 24200), bore P2-77, Millstream aquifer, Western Australia, Australia (BES 4012), 21°35'S, 117°03'E, 20 October 1996, W.F. Humphreys.

Paratypes

Australia: Western Australia: 3 ♀, 1 ♂ (WAM C 24201), same data as holotype.

Description

Female

Length of holotype, excluding antennule and caudal setae, 404 μm; range of length of paratypes 381–419 μm. Rostrum (Figure 43) subtriangular, with 2 sensilla.

Genital double somite (Figure 49) slightly longer than wide, ornamented with 2 sensilla on dorsal surface, 2 pores on ventral surface and 2 group of pores dorsally. Anal somite bearing pair of dorsal sensilla and 2 pores.

Caudal rami (Figure 49) about 1.5 longer than wide, outer spine longer than segment and about twice longer than the innermost.

Material Examined

Holotype
♀ (WAM C 24200), bore P2-77, Millstream aquifer, Western Australia, Australia (BES 4012), 21°35'S, 117°03'E, 20 October 1996, W.F. Humphreys.

Paratypes

Australia: Western Australia: 3 ♀, 1 ♂ (WAM C 24201), same data as holotype.

Description

Female

Length of holotype, excluding antennule and caudal setae, 404 μm; range of length of paratypes 381–419 μm. Rostrum (Figure 43) subtriangular, with 2 sensilla.

Genital double somite (Figure 49) slightly longer than wide, ornamented with 2 sensilla on dorsal surface, 2 pores on ventral surface and 2 group of pores dorsally. Anal somite bearing pair of dorsal sensilla and 2 pores.

Caudal rami (Figure 49) about 1.5 longer than wide, in ventral view. Only 6 setae present; seta I absent; seta II located on dorsal surface, about 75% of distance along rami; seta VI about 2 times longer than seta III; seta IV and V well developed; seta VII less than twice longer than rami. A group of cilia is present on dorsal inner surface, about 30% of distance along rami.

Antennule (Figure 41) 12-segmented: Number of setation elements as follows: 8 + aesthetasc, 4, 2, 2, 2+2 aesthetasc, 2, 3, 2, 2, 3, 2+2 aesthetasc, 2, 3, 2, 3, 8. Most setae sparsely plumose. Proximal segment with a row of small spinules at the basis of ventral surface.

Antenna (Figure 42) 4-segmented, excluding unarmed coxa. Basis bearing 2 setae around inner distal angle and ornamented with one spinule row along ventral margin, and 3 spinule rows on the dorsal side; exopodal seta absent. Endopod 3-
Figures 41-50  *Diacyclops esula* sp. nov., 45, 47-50 (holotype), 41-44, 46 (paratype): 41, ♀ antennule; 42, antenna; 43, rostrum; 44, labrum; 45, maxilla; 46, ♂ abdomen (ventral view); 47, ♀ leg 5; 48, leg 4; 49, ♀ abdomen (ventral view); 50, leg 1.
Cyclopids from basin and craton aquifers

segmented; first segment with inner medial seta and patch of spinules along the outer margin; second segment with 6 setae (2 along the inner margin, 4 arranged along inner part of distal margin); third segment armed with 7 setae.

Labrum, posterior part bearing numerous teeth, the lateral ones stronger, remaining ornamentation as in Figure 44. Paragnaths, mandible, maxillule and maxilliped without differences as compared to D. reidae; maxilla similar to that of D. reidae except for the spine on the distal coxal endite not bifid.

Swimming legs 1 to 4, 3-segmented. Coxa armed with inner plumose seta and ornamented with rows of small anterior and posterior spinules. Basis of leg 1 with long outer seta, inner spine reaching about one half of the second endopodal segment. Outer spines on the exopods of legs 1 ornamented as in Figure 50. Endopod 3 of leg 4 (Figure 48) about 1.2 times longer than wide, outer spine much longer than segment and more than twice longer than the innermost.

Spine and seta formula as follows:

- **Coxa basis endopod exopod**
  - leg 1: 0-1 1-1 0-1; 0-1; 1, 1+1, 2 1-1; 1-1; II, 1, 3
  - leg 2: 1-0 1-1 0-1; 0-1; 1, 1+1, 2 1-1; 1-1; III, 1, 3
  - leg 3: 0-1 1-0 0-1; 0-2; 1, 1+1, 2 1-1; 1-1; III, 1, 3
  - leg 4: 0-1 1-0 0-1; 0-2; 1, 1, 2 1-1; 1-1; III, 1, 3

Fifth leg (Figure 47) 2-segmented; protopodal segment narrow, bearing outer plumose seta; exopodal segment about twice as long as wide, bearing 1 plumose seta and one setiform spine distally, both longer than segment.

Sixth leg (Figure 49) bearing 2 spines and one seta.

**Male**

Body length 362 μm (Figure 46). Antennule digeniculate, 16-segmented. Setation as in D. reidae.

All other appendages as in female except for sixth leg, forming opercular plates bearing 1 plumose spine and 2 setae.

**Discussion and comparison**

*Diacyclops einslei* and *Diacyclops reidae* belong to the *Diacyclops crassicatidis*-complex (Reid, 1992), characterized by a 12-segmented antennula and all rami of the swimming legs 3-segmented. Within this complex both the new species share with *D. humphreysi*, *D. allicola* Kiefer, 1935, from India and *D. longifurcatus* Shen and Sung, 1963, from China, the peculiar characteristic of the inner apical spine of the leg 4 endopod shorter than the outer.

*Diacyclops reidae* and *D. einslei* are very close to *D. humphreysi*. The main differences seem to the shorter caudal rami, the presence of inner seta on the P1–P4 exopod 1 (versus seta absent), the presence of 2 setae on the P3 endopod 2 (versus 1 seta only).

*Diacyclops reidae* and *D. einslei* are easily distinguished by remarkable differences, such as the different armature of the basipodite of the antenna, the different morphology and spines of the labrum, the presence of a bifid spine on the distal coxal endite of the maxilla in *D. reidae* (versus spine not bifid), intercoxal sclerites of swimming legs with row of spinules in the *D. reidae* (versus naked intercoxa), the length of the P4 endopod 3 (about 1.2 and 1.7 times longer than wide in *einslei* and *reidae* respectively), and the length of the genital double-somite, wider than long in *reidae*, slightly longer than wide in *einslei*.

**Etymology**

The species is dedicated to U. Einsle in recognition of his fundamental contribution to knowledge of copepods.

**Genus Microcyclops** Claus, 1893

*Microcyclops variicans* (G.O. Sars, 1863)

**Material Examined**


**Remarks**

*Microcyclops variicans* is a cosmopolitan and ubiquitous cyclopoid, known from both epigean and underground fresh and brackish water bodies throughout the Australian continent (Pesce et al. 1996a).

**Genus Metacyclops** Kiefer, 1927, sensu Lindberg, 1961

*Metacyclops mortoni* Pesce, De Laurentiis and Humphreys, 1996

**Material Examined**


**Remarks**

*Metacyclops mortoni* is apparently a stygobiont species, endemic to northwestern Australia — it is
known from groundwaters of the Cape Range peninsula, Ashburton River, Port Hedland and Cossack (Pesce et al. 1996a).

Genus Mesocyclops G.O. Sars, 1914

Mesocyclops brooksi Pesce, De Laurentiis and Humphreys, 1996

Material Examined


Remarks

Mesocyclops brooksi is apparently a stygobiont species, endemic to northwestern Australia – it is known from aquifers at Millstream and on the Fortescue and Ashburton Rivers (Pesce et al. 1996a).

ACKNOWLEDGEMENTS

We thank Carlos E. Rocha for useful information on the genus Halicyclops, Juliane Waldock for her unstinting support, the lessees of Yalleen, Coolawanyah, Mardie and Yarraloola Stations, and the numerous officers of the Water and Rivers Commission, the Water Corporation, and the Coolawanyah, Mardie and Yarraloola Stations, and Halicyclops, on the genus Julianne Waldock for her

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P. De Laurentiis, G.L. Pesce, W.F. Humphreys


Cyclopids from basin and craton aquifers


Manuscript received 5 February 1998; accepted 9 October 1998.
First description of the nest and eggs of the Black Grasswren  
*Amytornis housei* (Milligan) with notes on breeding

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Abstract - Details of ten nests and four clutches of eggs are given for the Black Grasswren (*Amytornis housei*). Breeding occurs mainly during the wet season from December to March. Nests are large dome or oval shaped structures with a spout like entrance built in clumps of *Triodia*. Two eggs (rarely one) form the clutch and only the female incubates and broods. Additional notes are also provided on the distribution and ecological status of this endemic Western Australian species.

INTRODUCTION

The Black Grasswren *Amytornis housei* was first described by Milligan in 1902 from specimens collected by Dr F.M. House during the Brockman surveying expedition to west Kimberley, Western Australia, in 1901. The species was not recorded again until 1968 when further specimens were collected at Manning Creek and on the Barnett River, west Kimberley, by the Fifth Harold Hall Australian Expedition (Freeman 1970). Since that time the Western Australian Museum, often in conjunction with other State departments and naturalists, has carried out extensive survey work in north-west Kimberley and the distribution and status of this species has been more clearly defined. Although moderately common to common throughout its range almost nothing was known about its nidification with its eggs still undescribed. This was largely due to the fact that it breeds during the wet seasons in a very remote, inaccessible and rugged part of the State. This region of north-west Kimberley is so rugged and trackless that the composition and distribution of its fauna have only been fully known in the last 25 years. The only previous indication of breeding for the Black Grasswren comes from a female with a hard shelled egg in the oviduct collected by R.E. Johnstone at Crystal Head (14°28’S, 125°51’E) on 25 January 1973 and an empty new nest found at the same time. This nest was dome shaped about 20 cm long, 15 cm wide with an entrance hole about the centre of the nest. It was constructed of *Triodia* and grass and concealed in a large *Triodia* clump in an area of sandstone-spinifex. A fledgling just able to fly was also caught by hand at Surveyors Pool by Johnstone on 11 February 1973 and another just out of nest was photographed on a tributary of the Glenelg River by K. Coate on 23 May 1988.

Based on these dates as an indication of breeding, a short expedition to the Mitchell Plateau, was undertaken and funded by Nicholas Kolichis in February 1998 specifically to find nests and eggs of this species. On 2 February 1998 a team of ornithologists namely: N. Kolichis, R.E. Johnstone, P. Stone, K. Oakley, A. Oakley and T. Bush, flew in a large fixed winged aircraft and helicopter from Kununurra to Mitchell Plateau airstrip. From this airstrip people and equipment were ferried by helicopter to a base camp on Mertens Creek at 14°14’S, 125°42’E. The Mitchell Plateau area had received a considerable amount of rain (200–400 mm) from a large tropical low pressure system (ex tropical cyclone Les) that remained over the area for three days prior to our visit. Apart from flooded creeks caused by the heavy rain there appeared to be little wind or other damage to the vegetation. Much of the region had been burnt the previous year.

DISTRIBUTION, STATUS AND HABITAT

The Black Grasswren is confined to the subhumid north-west Kimberley, of Western Australia, from Admiralty Gulf (Crystal Head), south through the Mitchell Plateau (vicinity of Surveyors Pool, Mitchell River Falls) and Prince Regent River to Charnley River and Manning Creek (at 8 km SSW and 24 km S of Joint Hill (Storr 1980) (Figure 1). It is common to moderately common in pairs and small parties (up to eight). Mainly in pairs and family parties during the breeding season and larger groups when not breeding. Its habitat is mainly heavily dissected sandstone areas, immensely rugged with massive boulders forming the most remarkable shapes, lying in tiered terraces cut through by deep and narrow fault lines and in parts
overgrown with tropical vegetation. The vegetation ranges from low open woodland, tall shrubland or tall open shrubland. Trees and shrubs include *Eucalyptus miniata*, *E. brachyandra*, *E. hebertiana*, bloodwoods (*Corynia* spp.), *Oxvricia verticosa*, *Acacia* spp. (including *F. virens* var. *sublanceolata* and *F. platypoda*), *Brachychiton* spp., *Verticordia cunninghamii* and *Xanthostemon paradoxus*. The ground cover is mainly spinifex *Triodia pugnens*. See Figure 2.

**DISCOVERY OF NESTS**

Despite the inclement weather just prior to our arrival, breeding was well under way with most birds in pairs and some with fledged young. Pairs were vocal especially in early morning with males often calling from a high vantage point. Territorial disputes between two or occasionally up to four pairs were often observed, and birds reacted quickly during the day to playback calls. Nests were located by following birds, by searching all spinifex clumps where pairs had been seen or heard and by disturbing or flushing a sitting female. Once the first nest had been found the immediate area of about 3 km² was searched for nests. A total of five days were spent in the area and ten nests were found including four complete and ready for eggs, one with female sitting, four with eggs and one with a feathered nestling. Also two partly built nests and a number of old nests were located. Details of ten nests are given below in the order they were found.

**Nest 1.** Found on 2 February 1998 above Mertens Falls. Female flushed from nest. The nest site was in the top, centre, of a large clump of *Triodia pugnens* growing between two sandstone boulders. It was 400 mm above ground in the outer spines and was roughly globular, slightly flattened vertically, with
Figure 2  Typical habitat of Black Grasswren near Mitchell River Falls.

Nest and eggs of the Black Grasswren

made mainly of dry Triodia stems, dry leaves (mostly Eucalyptus) also pieces of bark, and lined with fine Triodia stems.

Nest 3. WAM A 26694. Found on 3 February near Mitchell River Falls. Nest with a single feathered nestling was located in a dense clump of Triodia pungens 1 m high, growing in a sandstone gutter about 4 m deep. The nestling was making a begging 'seeper' call from the nest. This nest was built about 0.5 m up in centre of Triodia clump. It was very damp probably from run-off from the sandstone walls on each side. The nest shape and materials were similar to those of nests 1 and 2 except for a larger number of leaves used. It measured 200 mm long, 130 mm wide with a circular entrance 60 mm diameter. Nestling WAM A26692; total length 122 mm; weight 18.5 g; iris brown; bill upper mandible slate, lower mandible whitish with a grey base and tip; gape yellow; mouth yellow; legs grey. Both adults were observed feeding the nestling.

Nest 4. Found on 4 February just west of Mertens Falls. In an area of heavily dissected sandstone boulders with scattered Acacia, Ficus and Xanthonostemon and a ground cover of mainly Triodia. A fairly conspicuous nest built in top centre of a large green Triodia pungens. This nest resembled a large slightly flattened dome, 160–170 mm long, 160 mm deep, circular entrance 45 x 40 mm (facing NW), interior 80 mm wide and 55 mm deep (egg cavity), spout like landing 130–140 mm long. It was made mainly of dry Triodia stems, dry leaves of Acacia and Eucalyptus bound tightly together with a number of Triodia stems extending from the entrance forming a landing and thickly lined with fine pieces of Triodia forming a hard base. It contained two fresh eggs; they were oval; 21.96 x 16.62 mm and 21.68 x 16.75 mm; smooth, pearly white slightly lustrous; sparsely spotted, speckled and blotched with blackish brown and chestnut brown mainly on larger end (but not forming a cap). Clutch set-marked 6/98 AO. See Figures 3 and 4.

Nest 5. WAM A 26793. Found on 4 February, just west of Mertens Falls, about 250 m from nest four in similar habitat. This nest was built in top of a large clump of Triodia pungens and fine creeper growing on a sandstone ridge. The nest was 80 mm above ground and resembled a tightly woven dome, 190 mm high and 100 mm wide, entrance 55 x 40 mm, interior depth of egg cavity 75 mm. It was made of dry stems of Triodia, dry leaves of Acacia, Ficus and Eucalyptus, several green leaves of Tinospora smilacina and lined with fine pieces of Triodia. There was no entrance landing. It contained two eggs; they were oval; 22.02 x 15.88 mm and 21.90 x 16.24 mm; smooth pearly white slightly lustrous; sparsely spotted, speckled and blotched with blackish brown, chestnut brown and with underlying markings of purplish grey mainly on larger end. Clutch set marked 7/98 AO. Figure 4.
Nest 6. WAM A 26716. Found on 6 February near East Falls among heavily dissected sandstone boulders. Nest built in centre top of a large clump of *Triodia pungens* growing in crevice 2 m long × 60 cm wide between two sandstone boulders. This nest shaped like a flattened oval, 220 mm long and 140 mm wide, internally 140 mm × 45–50 mm deep (egg cavity), entrance 50 mm wide with a short awning over top. It was made mainly of dry *Triodia pungens* stems, dry leaves of *Acacia* and *Eucalyptus*, dry tendril like rootlets and lined with coarse dry leaves. It contained two eggs; they were long oval; 21.70 × 15.8 mm and 21.09 × 16.16 mm; smooth pearly white slightly lustrous; sparsely spotted, speckled and blotched with reddish brown and chestnut brown mostly on larger end forming a sparse cap. Clutch set marked 8/98 KO. Figures 4 and 5.

Nest 7. WAM A 26722. Found on 6 February near East Falls in sandstone area regenerating after fire. Female flushed from nest. Nest built in regenerating *Triodia* clump on side of a steep ridge above a watercourse. This nest a large lightly woven dome built 15 cm above ground in outer spines of *Triodia* and measured 165 mm long, 160 mm wide, internally 100 cm × 55 mm (egg cavity), entrance 50 × 40 mm. It was constructed of dry *Triodia* stems, fine rootlets and dry leaves of *Acacia* and *Eucalyptus* and lined with fine pieces of *Triodia* and rootlets. It contained two well patterned eggs they were; long oval; 22.27 × 15.74 mm and 21.22 × 15.61 mm; smooth, pearly white, slightly lustrous; spotted and blotched with blackish brown, purplish brown and brown, mainly at larger end forming an irregular zone or cap. Clutch set marked 9/98 KO.

Nest 8. WAM A 26723. Found on 4 February with female sitting but empty and not collected until 7 February when female flushed but nest still empty. Nest built 50 cm above ground in a large *Triodia pungens* clump entangled with fine prickly creeper, growing in a crevice between sandstone boulders. It was well concealed and more typically dome shaped 320 mm long and 120 mm wide, internal nest chamber 80 mm deep, entrance 50 × 40 mm

Figure 3 Site of nest four of Black Grasswren, left to right A. Oakley (marking nest position), N. Kolichis and K. Oakley.
Nest and eggs of the Black Grasswren

(facing SE). Constructed mainly of dry *Triodia* stems, dry leaves of *Acacia* and *Eucalyptus* and dry tendrils of rootlets, and lined with dry leaves and fine pieces of *Triodia*. Several *Triodia* stems were bent over forming a landing at entrance.

**Nest 9.** Found on 8 February about 500 m east of Mertens Falls among small sandstone boulders and green regenerating *Triodia*. This nest a conspicuous flattened oval shape 200 mm long and 155 mm wide, internal cavity 165 mm and 60 mm deep (egg cavity), entrance 75 x 60 mm (facing SE), spout shaped landing of *Triodia* stems 160-165 mm long. Nest materials were similar to other nests.

**Nest 10.** Found on 8 February near camp on Mertens Creek in area of jumbled sandstone with sparse *Triodia* and scattered *Ficus*. Pair were observed here on 6 February. This nest was complete and ready for eggs. It was built in a small *Triodia* clump on a flat sandstone boulder. Nest a typical dome, 170 mm long and 115 mm wide, with internal nest cavity 90 mm wide and 70 mm deep, entrance 75 mm wide (facing S) and with a very long 300 m spout like landing of *Triodia* stems bound into the base of the nest. Nest materials similar to other nests including dry *Triodia* stems, dry leaves and rootlets, and lined with fine pieces of *Triodia*.

**Figure 5** Nest 6 of Black Grasswren A26716. Drawn by Danielle West.

**Figure 6** Nest 9 of Black Grasswren, a very conspicuous nest in regenerating *Triodia*.

**STATISTICAL SUMMARY OF NESTS**

The location, direction nest entrance faced and measurements of nests 1-10 are summarised in Table 1. The measurements taken are shown in Figure 7.

**DISCUSSION**

The Black Grasswren breeds during the austral summer (wet season), laying from December to March. It also appears, based on juveniles observed during this and other surveys, that they may also respond to local heavy rains, possibly breeding as late as May in some areas. Their nests are large, bulky structures ranging from dome shaped to flattened oval and are constructed mainly of interwoven *Triodia* stems, leaves and rootlets and lined with dry leaves and fine pieces of grass. The thick walls provide protection from the heavy rain and most nests also had a spout-like landing at the entrance. No consistency was evident in the choice of nest site. Nest sites varied from being well concealed and protected in dense clumps of *Triodia* between sandstone boulders, to very conspicuous placed among the top stems of *Triodia* clumps. A
Figure 7 Schematic front (left) and side (right) profiles of Black Grasswren Nests to show parameters measured, and presented in Table 1: a = nest height-length; b = nest width; c = nest chamber width; d = nest cavity depth; e = entrance depth; f = entrance width; g = landing length.

Table 1 Nest number, direction entrance faced, height above ground and measurements (mm) as indicated in Figure 7 of ten nests of *Amytornis housei*.

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number of nests had one or more old nests adjacent or within a few metres indicating that birds use the same area over subsequent seasons and build a new nest every year. Nests were found among huge jumbled boulders and in less rugged more open situations.

Judging from our observations only the female incubates and broods, leaving the nest in early morning (and possibly also at dusk) to feed with the male. When incubating she sits quite tightly at the approach of danger often only flushing if the clump or nest is touched. Both parents were observed feeding nestlings and fledged young. Both parents also were observed in rodent-runs, with wings open and partly dragging and tail lowered and spread, performed when intruders were close to nests with nestlings or to fledglings.

During the breeding season males were very noisy calling from tops of boulders, signalling position, usually with the female nearby giving contact calls. The males’ territorial song often eliciting a quick response from neighbouring pairs. Territorial disputes are common sometimes bringing several pairs together with noisy chattering. An indication of relative abundance of the birds can be judged from a total of 16 pairs that were counted in a 2 km transect following a narrow band (50-60 m wide) of sandstone fringing a creek south-west of Mertens Falls. After breeding the family unit appears to stay together and may unite with other groups from adjacent areas.

The nest of the Black Grasswren is similar in shape, construction and materials to that of the White-throated Grasswren *Amytornis woodwardi* of Arnhem Land, Northern Territory. Nests of *A. housei* ranged in size from 160-320 mm high or long x 100-160 mm wide with entrance 45-75 x 40-75 mm. The single nest of *A. woodwardi* described by Schodde (1982) measured 160-180 mm high x 120-140 mm wide with entrance 40-50 mm.

In size the eggs of *A. housei* are also similar to those of *A. woodwardi* ranging from 21.0-22.2 mm long x 15.6-16.7 mm wide (mean 21.7 x 16.0) compared to a clutch of two of *A. woodwardi* 22.3-22.5 x 15.6-15.9 mm. In colour however the eggs of *A. housei* are the least marked of all *Amytornis* being
Nest and eggs of the Black Grasswren

most like the very sparsely marked clutches of the Eryean Grasswren *A. goyderi* and considerably less marked than the single clutch of *A. woodwardi*. As a group *A. housei*, *A. woodwardi*, *A. dorotheae* and *A. goyderi* have poorly marked eggs whereas *A. barbatus*, *A. purnelli* and *A. textilis* have more extensively patterned eggs.

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We are grateful to P. Stone, K. Oakley, A. Oakley and T. Bush for their work in the field, often in trying conditions and to G. Lodge for his help in organising the expedition and providing logistical support. We also thank Dr R. Schodde for the loan of specimens.

REFERENCES


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A new Pliocene terebratulid brachiopod from the Roe Calcarenite, Eucla Basin of southern Australia

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Abstract - The terebratulid brachiopod, *Neothyris rylandae* sp. nov., is described from the Pliocene Roe Calcarenite in the Eucla Basin of southern Australia. This is the earliest record of the genus from Australia, all previous records being of extant species. *Neothyris* is also recorded from the Miocene to Recent of New Zealand and Antarctica.

INTRODUCTION

The Roe Calcarenite is a thin, sandy limestone that forms the surface of the Roe Plains in the southern Eucla Basin. It comprises poorly bedded, medium to coarse grained porous shelly calcarenite (Lowry 1970: 121–124). It has a very rich fauna dominated by calcareous algae, foraminifers, molluscs (Ludbrook 1978, and Kendrick *et al.* 1991) and, to a lesser extent, echinoids (Foster and Philip, 1980, and McNamara 1996). The Roe Calcarenite covers most of the Roe Plains in the western Eucla Basin to a thickness of about 1.5 m. It is rarely exposed and is usually obscured under soil or sand. Natural sections are uncommon, but numerous borrow pits adjacent to the Eyre Highway have provided stratigraphical information not otherwise available. The type section is the entrance doline of Nurina Cave 10 km south of Madura Roadhouse. The thickest section appears to be at Eucla N’1 well where it is up to 7.5 m (Lowry 1970).

The terebratulid brachiopod, *Neothyris rylandae* sp. nov., described in this study represents the only brachiopod yet known from the Roe Calcarenite and was collected from borrow pits in the Hampton Repeater Tower area. The stratigraphy is illustrated in Figure 2.

The Roe Calcarenite unconformably overlies a wave-abraded surface of Abrakurrie Limestone in central and western sections of the plain. To the east it unconformably overlies the Wilson Bluff Limestone. In the western and coastal areas it is overlain by coastal dunes. At the foot of the Hampton Escarpment, the northern boundary, it is overlain by colluvium whilst elsewhere it is covered by clay soil with kankar nodules (Lowry 1970).

Ludbrook (1978) suggested an Early Pleistocene age for the unit. The presence in the Roe Calcarenite of a species of arcaid bivalve genus *Cuculla*, which is not known from post-Pliocene sediments elsewhere in southern Australia casts doubt on Ludbrooks’s age estimate (Darragh 1985, Table 2). The most important correlative fossil in the Roe Calcarenite is the presence of species of a gastropod genus *Hartungia* which in New Zealand is essentially confined to the Pliocene (Beu and Maxwell 1990). This suggests a Pliocene age for the deposit (Kendrick *et al.* 1991).

The genus *Neothyris* has been regarded as a genus endemic to New Zealand and the Subantarctic islands off the southern and southeastern coast of the South Island (Neall 1972). It is “the most widely distributed subtidal brachiopod genus on the continental shelves surrounding New Zealand and the islands of the Campbell Plateau” (Chapman and Richardson 1981).

Bitner and Piseria (1984) describe a specimen from the Pliocene Polonez Cove Formation of King George Island of the South Shetland Islands of Antarctica as a *Neothyris*. As only a single specimen was available, the description lacks detail, as does the photograph supplied. Two species, *Neothyris cf. thomsoni* Allan, 1932 and an unnamed species of *Neothyris* are recorded by Biernat *et al.* (1985) from Middle to Late Miocene deposits of the Moby Dick Group of King George Island.

*Neothyris* is represented by five species and three subspecies in the fossil record from the Miocene to Early Pleistocene of New Zealand (Neall 1972). Three living species have been recognized. They are *N. dawsoni* Neall, 1972 and two subspecies (*N. lenticularis* *lenticularis* (Deshayes, 1839) and *N. l. compressa* Neall, 1972). However, Chapman and Richardson (1981) consider the latter taxa to be separate species. Living *Neothyris* have been observed as both free-lying (Richardson 1981) and attached (Grange *et al.* 1981).

All the material examined in this study is housed in the collection of the Western Australian Museum (WAM). Photographs were taken using a Nikon F 90 X camera with a macro lens and specimens coated with ammonium chloride.
Figure 1 Locality map for the Roe Calcarenite and the Hampton Microwave Repeater tower.

SYSTEMATICS

Superfamily Terebratelloidea King, 1850
Family Terebratellidae King, 1850
Subfamily Terebratellinae King, 1850
Genus *Neothyris* Douville, 1879

Type Species
*Terebratula lenticularis* Deshayes, 1839.

Remarks
All recorded species of *Neothyris* to date have come from the South East Pacific Ocean, primarily around New Zealand and its associated islands. These include *N. anceps*, *N. novara*, *N. iheringi* and *N. obtusa* from the Miocene, *N. thomsoni*, *N. campbellica* (*N. c. ovalis* and *N. c. campbellica*) and *N. obtusa* from the Pliocene and *N. campbellica elongata* from the Pleistocene. The living species are *N. dawsoni*, *N. lenticularis* and *N. compressa* (Neall 1972). Neall (1972) stated that the living species are found only in New Zealand and Subantarctic waters (Stewart Island, Pukaki Bank, Auckland Islands, Antipodes Islands, Campbell Island).

Thomson (1927) suggested that *Neothyris* “is merely a *Pachymagas* which has attained the magellaniform loop stage”. MacKinnon (1987) questioned the existence of *Pachymagas* but gave no alternative name to replace it. Examination of the fossil and extant species of *Neothyris* led Neall (1972) to suggest an evolutionary trend toward a smaller foramen and a more incurved beak. In Recent species, the shell shape, cardinal process and degree of curvature of the beak of *Neothyris* appear to vary even within single populations and across a given species, according to the environment in which they are found (Neall 1972).

*Neothyris rylandae* sp. nov.
Figures 3 A–F and 4 A–C

Material Examined
Holotype
WAM 82.2368; Roe Plains, Madura district, Western Australia, Australia. Pit 1.5 km N of Hampton Microwave Repeater Tower. Basal 0.4 m carbonate sand.

Paratypes
Australia: Western Australia: WAM 69.382; Roe Plain, 25 miles east of Madura- south side of Eyre Highway. Bulloozed pit approx. 3 m deep.
WAM 75.178, WAM 76.2480; Roe Plain, Eucla Basin, Quarries beside road from Eyre Highway to Hampton Microwave Tower.
WAM 82.2367, 82.2369, 82.2370, 82.2372, 82.2373, 82.2378; Roe Plains, Madura district, Pit 0.5 km N of Hampton Microwave Repeater Tower. Basal 0.6 m carbonate sand.
WAM 85.2026, 82.2374, 82.2376, 82.2377, 82.2379–82.2388; Roe Plains, Madura district, Pit 1.5 km N of Hampton Microwave Repeater Tower: spoil heaps near base of tower.
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**DEPT**

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<tr>
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<td>1.45</td>
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<td>1.60</td>
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<td>Pale grey rubbly calcarenite unevenly cemented with pockets of pink clayey sand; scattered shells more common towards top</td>
</tr>
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<td>3.15</td>
<td>Pale (pink when moist), fine, silty carbonate sand with abundant fossils including <em>Neothyris rylandae</em>.</td>
</tr>
</tbody>
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**Figure 2** Section of the Roe Calcarenite at the type locality in pit 1.5 km north of Hampton Microwave Repeater Tower. (31°57'36"S 127°34'45"E). Courtesy G. W. Kendrick (personal communication).
Figure 3  *Neothuris rulandae* A, WAM 82.2368, Holotype, dorsal valve exterior x 1; B, WAM 82.2368, Holotype, lateral margin x 1; C, WAM 82.2368, Holotype, anterior commissure x 1.5; D, WAM 82.2378a, Paratype, ventral valve interior x 1; E, WAM 82.2367b, Paratype, ventral valve interior x 2.5; F, WAM 82.2367a, lateral view of the brachial valve x 1.5.
Figure 4  *Neothyris rylandae*  A, WAM 82.2378b, Paratype, internal view of dorsal valve x 2.5; B, WAM 76.2480, Paratype, internal view of dorsal valve x 2; C, WAM 82.2367a, Paratype, internal view of dorsal valve x 2.
Description

External

Shell large (up to 65 mm in length), ovate to subpentagonal, biconvex, both valves approximately equal, greatest width just anterior to midlength, width 80% of length; lateral margins rounded, anterior margin bevelled; cardinal margin strongly curved, 60% of shell width; lateral commissure convex towards ventral valve, crenulate anterior to midlength; anterior commissure sulcate to incipiently intraplicate; ventral valve with keel developing posteriorly and widening until anterior commissure where it generates a fold.

Surface smooth, growth lines towards anterior commissure very prominent; punctae fine and regularly dense; beak suberect to erect, truncated, labiate; beak ridges wide, rounded meeting dorsal valve indistinctly anterior to cardinal margin; foramen round, large, 6% of shell length, mesothyridid; symphytium narrow, deeply concave, deltidal plates conjunct, without obvious median ridge.

Internal

Ventral valve. Pedicle collar short and thin; trench leading into pedicle area created by thickened posterior sides of valve; muscle scars a pair of furrows either side of pedicle neck, diverging and extending to midlength; hinge teeth strong, facing inward at a slight angle; grooved for reception of socket ridges; teeth wider than thick; hinge teeth bases swollen; no dental plates.

Dorsal valve. Sockets wide and deep; triangular with small roof posteriorly at apex; base anteriorly located; fulcral plate relatively thin; outer socket ridges sharp and slightly raised, extend slightly above hinge line, 12.5% shell length; inner socket ridges slightly raised; outer hinge plate joins inner socket ridge and crural bases to make V-shaped trough; inner hinge plates extend from crural bases to median septum, meeting medially to create a hinge trough; crural bases thin, extending from posterior of shell to crura; crural process dart to talon shaped, vertical with slight anteriomedial curve producing a sharp point; median septum extends posterior of midlength; raised posteriorly, appearing to bifurcate where hinge trough meets it; base thickened posteriorly (crural bases and median septum swelling more pronounced with increase in size of valve); loop teleform (magellaniform), extending greater than 75% shell length; descending band thin and wide; ascending loop very wide near transverse band which is wide, incurved and arched towards ventral valve; cardinal process protuberant, round with raised margins laterally and anteriorly, anterior extends vertically to cardinal margin, swollen and extending into shell over hinge trough, raising the cardinal process well above the cardinalia.

Intraspecific variation

In the smaller specimens (4–6 mm) the deltidal plates are disjunct and the beak suberect. From 11 mm – 43 mm the deltidal plates are conjunct, the beak is suberect but “moving” to the erect position and crenulations are non existent to incipient.

One specimen, WAM 82.2367, is similar in all features described above except for the following variations:

Ventral valve (Figure 3E): Foramen small (3.5% shell length). Pedicle collar thick. Hinge teeth upwardly curved; Considerable posterior shell thickening. Pedicle trench very narrow with near vertical sides formed by extended hinge teeth bases.

Dorsal valve (Figure 4C): Sockets deeper. Brachidium has wider bands to the loop. Cardinal process bilobed (cardinal wings; Neall 1972) and a flattened ridge extends from the cardinal margin. Two further “wings” are formed on either side which extend vertically down towards valve floor giving the impression of a “winged keel”. The anterior vertical surface is convex, filling the area between the crural processes. The median septum is swollen below the hinge trough and the swollen area extends anteriorly, tapering as it does so.

WAM 76.2480 (Figure 4B), an incomplete dorsal valve also adds to the known variation of the species. No brachidium is present. The socket base is very swollen. The medium septum is swollen under the hinge trough. These two areas of swelling result in a deep, narrow trench forming between them, below the crural processes. The crural bases are also swollen. The cardinal process shows the beginnings of the “winged keel” forming.

Etymology

The species is named after Ms Valerie Anne Ryland, a former technical officer at the Western Australian Museum and undertook the preliminary work on all the specimens from the Roe Calcarenite.

Remarks

Neothyris rylandae has similarities to that of Cudmorella, especially in the interior of the dorsal valve. Allan (1939) suggests that there is an affinity between Cudmorella and Neothyris but differentiates them on the basis of Cudmorella having a mesothyridid foramen and a primitive cardinal process whilst Neothyris has a mesothyridid foramen and is less folded. Neothyris rylandae has a mesothyridid foramen and the folding is incipient.

The primary areas of morphological difference between Neothyris species are in the overall size, degree of convexity, cardinal margin, anterior commissure, foramen size relative to shell length, socket teeth and cardinal process. Neothyris
A new pliocene brachiopod

*N. anceps* Thomson, 1920 (Miocene) is a large shell (53 mm long) with a large foramen and a convex lateral margin similar to *N. rylandae*, which has a maximum length of 65 mm. The cardinal process is described as being "confined to the posterior part of the hinge trough" (Thomson 1920) whereas in *N. rylandae* the cardinal process is very large and takes up the majority of the "hinge trough". Richardson (1994) suggests that the "hinge trough" used in the description of *Neothyris* is in fact a consequence of differential thickening of inner hinge plates based on her work on juvenile specimens. Few details are available for *N. novara* Ihering (Miocene). Thomson (1920) describes it as being more than half as deep as long, having a straighter hinge line and a less convex lateral margin than *N. lenticularis* *N. rylandae* is as bulbous but has a more strongly curved hinge line and lateral margin than *N. lenticularis*

*N. iheringi* Thomson, 1920 (Miocene) is medium sized (based on an illustration in Thomson (1920)), with a long beak and a small foramen. None of these features are comparable to those of *N. rylandae*, which is larger and has a larger foramen. The Pliocene *N. thomsou* Allan, 1932 is similar to *N. rylandae* in that it is of similar size, strongly biconvex, having deep sockets, a wide "hinge trough" and a large crural process (Allan 1932). It differs from *N. rylandae* in having a smaller foramen and a rectimarginate anterior commissure.

The Pliocene *N. campbelllica ovalis* (Hutton, 1886) differs from *N. rylandae* in that it has a rounded commissure, smaller sockets and a thin cardinal process. The size is moderate to large, as is the size of the foramen (Neall 1972). *N.c. campbelllica* (Filhol, 1885) from the Pliocene is described by Neall (1972) as moderate to large in size, narrow and having a small foramen, all these features differing from *N. rylandae*. *N. c. elongata* Neall, 1972 (Nukumaruan-Pleistocene) is a flattened shell of medium size and with a medium-sized foramen (Neall, 1972).

The living *N. lenticularis* (Deshayes, 1839) is large, but in comparison to *N. rylandae* it would better be described as medium sized. The cardinal process has a small median boss whilst in *N. rylandae* it is very swollen.

The living *N. compressa* Neall, 1972 is medium-sized with a maximum length of 50 mm, having a compressed biconvex appearance (Chapman and Richardson 1981). *N. rylandae* is bulbous and much larger. *N. dawsoni* Neall, 1972 (Recent) is small with a tiny foramen (Chapman and Richardson 1981). According to Neall (1972), *N. obtusa* ranges from the Pliocene to the Recent. The species is described as having a small "hinge trough", small hinge teeth and a small to medium-sized cardinal process, making it quite different from *N. rylandae* with a swollen "hinge trough", large cardinal process and large hinge teeth.

*N. rylandae* has a large foramen and a suberect to erect beak. The cardinalia and posterior sections of the shell are much thickened (see above description). According to Richardson and Watson (1975) and Richardson (1981, 1984) this would suggest that the species is capable of, and adapted to, a free lying habit. The presence of the labiate suberect to erect beak, concave symphysis and mesothyrid foramen would indicate an inert pedicle (Richardson, 1981) *N. rylandae* is found in sandy calcarenite and this is consistent with the life habit as described above.

**CONCLUSION**

Present species of *Neothyris* are restricted to cool waters around southern Australia, Antarctica and New Zealand. The Roe Calcarenite species, *Neothyris rylandae*, appears to have inhabited relatively warmer waters during the Late Pliocene (Hodell and Warnke 1991). Why is a supposed endemic New Zealand genus which is believed to have evolved in New Zealand waters in the Middle Miocene (Neall 1972), found in the southern regions of Western Australia in the Late Pliocene? Two species of *Neothyris*, *N. cf. thomsoni* and another of uncertain species identity, are described from Early to Middle Miocene deposits of King George Island, South Shetland Islands, Antarctica (Biemat et al. 1985) as well as a single species of the genus of Pliocene age within the same group (Bitner and Pisera 1984). It is possible that these species, with *N. rylandae*, evolved from the same stock as the New Zealand *Neothyris* but that the ancestor was common to the mid-Tertiary of the Southern Ocean. Zinsmeister (1982, 1984) suggests that the high latitude region of the southern hemisphere acted as a centre of origin and dispersal for a broad spectrum of taxa. Precursors to modern deep and shallow water mid-latitude forms evolved and flourished in the high latitudes until conditions in lower latitudes favoured their dispersal. Bitner (1994) also suggests that the late Tertiary and Recent faunas of Australasia originated in Antarctic waters. Research on the brachiopods of the Late Paleocene deposits of northwest Western Australia (Craig, in preparation) suggests that a number of genera, common to southern Australia and New Zealand, evolved *insitu* along the southern Indo-Atlantic coastal region of Antarctica and Western Australia.

It is also possible that *Neothyris rylandae* evolved from New Zealand stock and moved east to west during a hiatus in the Leeuwin Current during the Late Pliocene (McGowran et al. 1991). This would not however explain the presence of the genus in Antarctica during the Miocene. Until other species of this genus are located in Late Tertiary deposits in either Australia or Antarctica, the origin of the genus remains unclear.
ACKNOWLEDGEMENTS

I wish to thank Mr G.W. Kendrick for his advice with the stratigraphy of the Roe Calcarenite and Dr K.J. McNamara whose continued encouragement and constructive criticism has been invaluable. I would also like to thank the Western Australian Museum and the School of Applied Geology, Curtin University of Technology for provision of resources to complete this study. Dr C.J.S. deSilva provided a camera stand for photographing the specimens.

REFERENCES


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Measurements in millimetres: (VV = ventral valve, DV = dorsal valve)

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An extended description of the Pilbara Death Adder, *Acanthophis wellsi* Hoser (Serpentes: Elapidae), with notes on the Desert Death Adder, *A. pyrrhus* Boulenger, and identification of a possible hybrid zone

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Abstract — An extended description is provided for the Pilbara Death Adder, *Acanthophis wellsi*, based on material from throughout the Pilbara region and adjacent Cape Range Peninsula, Western Australia. *Acanthophis wellsi* was formerly confused with the Desert Death Adder, *A. pyrrhus*, but differs from this highly distinctive species in features of head scalation and hemipenial morphology as well as meristic parameters. Possible hybrids between the two species are identified from the Giralia – Cane River area where their distributions interdigitate. Several populations of *A. wellsi* show a striking pattern polymorphism involving melanism of the head and transverse body bands.

A pilot genetic analysis of a small number of individuals suggests that all of the species of *Acanthophis* are closely related. *Acanthophis wellsi* appears to be closest genetically to *A. pyrrhus*, but this may not denote a special cladistic affinity. A cladistic analysis of morphological characters identifies *A. wellsi* as a relatively plesiomorphic species, perhaps closest in overall body form to the common ancestor of all *Acanthophis* species.

INTRODUCTION

Australasian elapid snakes of the genus *Acanthophis*, commonly known as Death Adders, are found in most parts of Australia and New Guinea and west to the Indonesian island of Ceram. Despite a high level of public and scientific interest in these snakes, little basic taxonomic research has been undertaken on the group. Storr (1981) recognised three closely related species in Western Australia, which he tentatively identified as *A. antarcticus* (Shaw and Nodder), *A. praelongus* Ramsay and *A. pyrrhus* Boulenger. Unfortunately, Storr's plea for a thorough, Australia-wide revision of the group has not been taken up, with the result that his taxonomic concepts remain largely untested outside of Western Australia. Barnett and Gow (1992), Mitschin and Davis (1992), Ball (1993) and Hoser (1995) all alluded to the presence of additional undescribed species of *Acanthophis* in Australia. McDowell (1984) and O'Shea (1996) both commented on the confused state of taxonomy of New Guinean Death Adders.

The nomenclature of *Acanthophis* has been impacted by two works published by 'amateur' herpetologists in unrefereed contexts. Wells and Wellington (1985) proposed four additional species of *Acanthophis* in an "overview" of Death Adders, published in Monitor, the journal of the Victorian Herpetological Society. Hoser's nomenclature is a mixture of invalid usage based on unavailable Wells and Wellington names, together with several new names which minimally satisfy the terms of availability as defined by the International Code of Zoological Nomenclature (1985). One of the available Hoser names is applicable to a distinctive taxon from the Pilbara region of Western Australia, which the present authors had submitted for publication earlier in 1998. The status of Hoser's other proposed new taxa (*bottonii, crotalusei, cummingi, woolfi*) is currently uncertain and we recommend that these taxa not be taken into general usage until such time as the systematics of the genus is investigated in greater detail. Hoser's continued use of the Wells and Wellington *nomina nuda* "armstrongi", "lancasteri"
and "schistos" also introduces a further element of confusion into the taxonomy of this group.

In this paper we provide an extended description of the Pilbara Death Adder, which now bears the name *Acanthophis wellsi* Hoser (herein emended from *A. wellsi* Hoser). We also give an extended description of *A. pyrrhus* based on material from throughout its range, and present preliminary genetic evidence concerning the level of differentiation among the various species of *Acanthophis*. Finally, we identify a possible zone of hybridization between *A. wellsi* and *A. pyrrhus* based on morphological criteria.

**MATERIALS AND METHODS**

Specimens in the following collections were examined: Western Australian Museum (WAM); South Australian Museum (SAM); Queensland Museum (QM); and Northern Territory Museum (NTM). Specimens in the Australian Museum (AM) were examined on our behalf by Dr G.M. Shea of Sydney University. The sex of many specimens could be determined by examination of gonads; however, a significant number are either badly damaged or immature, and could not be reliably sexed. Specimens were judged to be 'adult' if they showed signs of reproductive maturity (i.e., enlarged ovarian follicles, elongate or expanded oviduct in females; enlarged testis, convoluted efferent duct in males).

The following standard measurements and counts were taken on all specimens: snout-vent length (SVL); tail length (TailL); ventral scale count [VSC; counted by the method of Dowling (1951)]; and midbody scale count (MSC). The subcaudal scales in *Acanthophis* consist of an anterior series of undivided scales, followed by a series of paired scales which grade onto the characteristic 'caudal lure' with its small spine. The undivided subcaudal scales (USC) and divided subcaudal scales (DSC) were counted separately. All measurements are given in mm.

Mensural and meristic data are presented by sex for each species, and for a 'pooled' sample which includes any unsexed individuals. The extent of sexual dimorphism and regional differentiation within each of *A. wellsi* and *A. pyrrhus* were explored using One-Factor ANOVA; results with $p < 0.05$ are treated as 'significant'. The hemipenis was studied in its everted condition in three individuals of *A. wellsi*; and in its retracted condition by dissection of one specimen each of *A. wellsi* and *A. pyrrhus*.

A series of animals from the Giralia – Cane River area of Western Australia are identified as possible hybrids between *A. wellsi* and *A. pyrrhus*. The mensural and meristic data for these specimens are presented separately, both on account of their intrinsic interest, and also to avoid any blurring of the distinction between the two parental taxa.

Frozen liver samples suitable for allozyme electrophoresis were available from seven individuals of *A. wellsi*, six individuals of *A. antarctics* derived from four populations, and one individual of each of *A. pyrrhus* and *A. praelongus*. Two individuals of *Echisops curta* (Schlegel) and one each of *Notechis scutatus* (Peters) and *N. ater* (Krefft) were also included as outgroups for cladistic analysis and to provide a broader perspective on interspecific and intergeneric genetic differentiation among the live-bearing Australian elapids, the evolutionary lineage to which *Acanthophis* most likely belongs (Greer 1998). Full locality details for all specimens employed in both the morphometric and genetic studies are provided in the Appendix.

Allozyme electrophoresis of liver homogenates was conducted on cellulose acetate gels ('Cellogel', Chemetron) according to the methods of Richardson et al. (1986). The proteins and enzyme products of a presumptive 39 loci were scored. The proteins stained, the abbreviations used and the Enzyme Commission numbers are: aspartate aminotransferase (AAT, EC 2.6.1.1), aconitase hydratase (ACOH, EC 4.2.1.3), aminoacylase (ACYC, EC 3.5.1.14), adenosine deaminase (ADA, EC 3.5.4.4), adenylyl kinase (AK, EC 2.7.4.3), aldehyde dehydrogenase (ALDH, EC 1.2.1.5), carbonic anhydrase (CA, EC 4.2.1.1), enolase (ENO, EC 4.2.1.11), esterase (EST, EC 3.1.1.?), fructose-bisphosphatase (FBP, EC 3.1.3.11), fumaric hydratase (FUMH, EC 4.2.1.2), glyceraldehyde-3-phosphate dehydrogenase (GAPDH, EC 1.2.1.12), guanine deaminase (GDA, EC 3.5.4.3), glutamate dehydrogenase (GDH, EC 1.4.1.3), glycerol-3-phosphate dehydrogenase (G3PDH, EC 1.1.1.8), glucose-6-phosphate isomerase (GPI, EC 5.3.1.9), alanine aminotransferase (GPT, EC 2.6.1.2), glutathione reductase (GSR, EC 1.6.4.2), L-iditol dehydrogenase (IDDH, EC 1.1.1.14), isocitrate dehydrogenase (IDH, EC 1.1.1.42), cytosol aminopeptidase (LAP, EC 3.4.11.1), L-lactate dehydrogenase (LDH, EC 1.1.1.27), lactoylglutathione lyase (LGL, EC 4.4.1.5), malate dehydrogenase (MDH, EC 1.1.1.37), mannose-6-phosphate isomerase (MPI, EC 5.3.1.8), nucleoside-diphosphate kinase (NDPK, EC 2.7.4.6), dipeptidases (PEP-A, EC 3.4.13.7), tripeptide aminopeptidase (PEP-B, EC 3.4.11.1), proline dipeptidase (PEP-D, EC 3.4.13.7), phosphoglycerate mutase (PGAM, EC 5.2.4.1), phosphoglucone dehydrogenase (P'GDH, EC 1.1.1.44), phosphoglycerate kinase (PGK, EC 2.7.2.3), phosphoglucomutase (PGM, EC 5.4.2.2), superoxide dismutase (SOD, EC 1.15.1.1) and triosephosphate isomerase (TIPI, EC 5.3.1.1). Alleles are designated in order of cathodal mobility (i.e., $a$ signifies least cathodal migration).
SYSTEMATICS
Acanthophis wellsi Hoser, 1998 (emended name)

Holotype
WAM R8886, immature animal of uncertain sex, collected by K.H. Burton at the Blue Asbestos Mine, Wittenoom Gorge, Western Australia, Australia in 22°15'S, 118°23'E. The specimen was accessioned on 26th November 1945.

Paratypes
Australia: Western Australia: WAM R21538 from Wittenoom Gorge; R17121 and R18493 from Wittenoom; WAM R67921 from 31 km SE Mt Mearry; WAM R56907 from Marandoo. Full locality details are provided in the Appendix.

Revised diagnosis
A relatively elongate, slender-bodied Acanthophis, usually with reddish ground colour, superficially similar to A. pyrrhus but differing in having prefrontals usually undivided (always divided in A. pyrrhus), less strongly keeled prefrontal scales, less rugose supraocular scales, smooth scales on flanks (keeled in A. pyrrhus) and more boldly patterned supralabial, infralabial and mental scales. Further differing from A. pyrrhus in having lower modal midbody scale count (19 vs 21), significantly lower ventral (123-141 vs 136-158) counts, and usually lacking any dark tipped scales along the posterior margin of each transverse dark band.

Diffs from A. antarcticus in more slender build and having lower modal midbody scale count (19 vs 21), more numerous ventral scales [110-124 in antarcticus; data from Storr (1981)] and usually more subdued dorsal patterning.

Diffs from A. praelongus in lacking strong lateral flanges on the supraocular scales (weakly developed in Cape Range population of A. zoellsi), and having lower midbody scale counts (modal count 19 vs 23) and usually more subdued dorsal patterning.

Description
Summary mensural and meristic data are given in Table 1, together with details of statistical tests for sexual dimorphism.

Table 1 Summary mensural and meristic data for Acanthophis wellsi, presented separately for male and female specimens and then for a ‘pooled’ sample which includes unsexed specimens. Results of One-way ANOVA are shown for each primary parameter. A significant level of sexual dimorphism is observed only in number of undivided subcaudal scales, with Tail Length approaching significance.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sex</th>
<th>N</th>
<th>Mean ± SD (Range)</th>
<th>ANOVA results</th>
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<tr>
<td>Snout-Vent Length</td>
<td>M</td>
<td>12</td>
<td>365.8 ± 47.50 (260-435)</td>
<td>F = 0.180, df = 24, p = 0.675</td>
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<td></td>
<td>F</td>
<td>13</td>
<td>355.8 ± 66.74 (237-443)</td>
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<td></td>
<td>all</td>
<td>40</td>
<td>328.8 ± 85.41 (141-443)</td>
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<tr>
<td>Tail Length</td>
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<td>12</td>
<td>71.8 ± 10.26 (54-84)</td>
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<tr>
<td></td>
<td>F</td>
<td>13</td>
<td>62.3 ± 13.17 (41-78)</td>
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</tr>
<tr>
<td></td>
<td>all</td>
<td>40</td>
<td>62.2 ± 17.98 (28-90)</td>
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<tr>
<td>Total Length</td>
<td>M</td>
<td>9</td>
<td>435.1 ± 63.27 (317-511)</td>
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<tr>
<td></td>
<td>F</td>
<td>13</td>
<td>422.8 ± 76.56 (250-520)</td>
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<tr>
<td></td>
<td>all</td>
<td>35</td>
<td>378.1 ± 111.57 (170-520)</td>
<td>F = 0.162, df = 22, p = 0.691</td>
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<td>Tail Length as % of Total Length</td>
<td>M</td>
<td>9</td>
<td>16.3 ± 2.07% (13-18%)</td>
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<td></td>
<td>F</td>
<td>13</td>
<td>14.9 ± 2.42% (11-18%)</td>
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<td></td>
<td>all</td>
<td>35</td>
<td>16.0 ± 2.00% (11-19%)</td>
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<td>Ventral body scales</td>
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<td>12</td>
<td>133.5 ± 3.32 (126-138)</td>
<td>F = 0.318, df = 24 p = 0.578</td>
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<tr>
<td></td>
<td>F</td>
<td>13</td>
<td>134.5 ± 5.52 (123-141)</td>
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<td>40</td>
<td>133.9 ± 4.05 (123-141)</td>
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<td>Subcaudal scales</td>
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<td>49.9 ± 3.13 (46-55)</td>
<td>F = 3.274, df = 16, p = 0.090</td>
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<tr>
<td></td>
<td>F</td>
<td>10</td>
<td>46.8 ± 3.62 (41-52)</td>
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<td>all</td>
<td>29</td>
<td>47.3 ± 4.01 (41-55)</td>
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<td>Undivided subcaudal scales</td>
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<td>28.6 ± 4.30 (24-39)</td>
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<td></td>
<td>F</td>
<td>15</td>
<td>21.1 ± 4.45 (11-28)</td>
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<td>25.9 ± 5.54 (11-39)</td>
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<td>Divided subcaudal scales</td>
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<td>F</td>
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<td>23.7 ± 3.75 (19-34)</td>
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<td>43</td>
<td>21.6 ± 4.85 (6-34)</td>
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<tr>
<td>Total ventral scales</td>
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<td>183.7 ± 5.85 (175-191)</td>
<td>F = 2.233, df = 13, p = 0.161</td>
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<td></td>
<td>F</td>
<td>8</td>
<td>178.5 ± 6.78 (168-188)</td>
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<td></td>
<td>all</td>
<td>23</td>
<td>180.4 ± 5.81 (168-191)</td>
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</table>
SVL 141–443 (n=40). Mean SVL for adult males (342.3) and for adult females (364.4) not significantly different. TailL 24–94 (n=40); or 11.5–19.3% of total length. Mean TailL of males (68.0) significantly higher than that of females (61.6).

Ventral scales 123–141 (n=40); mean ventral count of females (135.3) significantly higher than that of males (132.2). Subcaudal series consists of proximal undivided series, followed by divided series which terminate in weakly ‘caudal lure’ and spine. Combined subcaudal count is 43–63 (n=44), mean subcaudal count significantly higher in males (49.8) than females (44.4). Undivided subcaudals 13–39 (n=43), mean USC significantly higher in males (29.2) than females (21.1). Divided subcaudals 6–34, mean DSC not differing between sexes. Caudal 'lure' not markedly compressed and lacking any obvious specialization of scales except for presence of terminal spine. Tail tip usually white (71%; n=34), less often entirely dark (26%) or banded (3%).

Head pear-shaped, broadest across rear, narrowing abruptly onto facial region (Figure 2b,c). Snout relatively deep and foreshortened. Head scalation mildly rugose. Prefrontals generally undivided, one per side. Frontal and parietal scales with subdued, irregular sculpting. Single supraocular scale with subdued, irregular sculpting but lacking lateral flange. Preocular (93%, n=43), Postoculars usually 1 (77%), occasionally 3 (7%).

Numerous temporal scales usually arranged in 3+4+5 or 3+3+5 pattern. Primary temporals usually 3 (91%, n=43), occasionally 2 (7%) or 4 (2%). Secondary temporals usually 4 (58%) or 3 (30%), occasionally 5 (12%). Tertiary temporals usually 5 (86%), occasionally 4 (5%) or 6 (9%). Uppermost temporal scales with distinct keels; lower temporal scales smooth.

Rostral scale relatively high and narrow. Upper labials always 6 (n=43), fifth and sixth largest of series. 'Temporoalabial' scale (sensu McDowell 1970) here counted with secondary temporal series. Main features of head and body pattern can be seen in Figures 1a–c and 2. Animals exist in two some other variants including rare 'weakly-banded' main colour phases - 'typical' and 'mclanistic' - but individuals, are known. The 'mclanistic' sample includes individuals of both sex as well as immature animals. The primary description is of the 'typical' colour phase (Figure 1a); variants are noted as appropriate.

Body and tail are conspicuously banded in all but a few specimens. Bands are usually two longitudinal scales in width (occasionally 1 or 3), alternating between pale brick red to pale yellowish brown and darker reddish-brown to brown. There are usually 40–43 dark bands on the body, with a further 15 or so on tail. Conspicuous black spotting occurs across both anterior and posterior margins of dark bands on neck, but is generally confined to posterior margin of bands on mid- to lower body and on tail. In rare exceptions (e.g., WAM R125733) spotting is present across the anterior margin of bands throughout the entire length of the snake.

Crossbands become diffuse on lower flanks, giving way to two rows of black spots; these are strongest on the neck and weaken posteriorly. The lower row of spots is positioned on the outer margin of the ventral scales. Ventral scales are otherwise immaculate.

Head reddish-brown, often slightly darker than body; pigment extending over temporal scales and upper labials almost to oral margin. Lower labials usually with distinct, centrally located 'spots' of same colour; these are weak or absent in some individuals. Mental scale and adjacent chinshields usually with conspicuous 'inverted-V' mark; this is weakly developed in some specimens.

'Melanistic' individuals (Figure 1b) usually with black head and crossbands on yellowish-brown ground colour. Black spotting is usually discernible across anterior margins of dark bands. Facial pattern as in 'typical' phase. Some individuals (e.g., WAM R125736) have chocolate-brown head and pale chocolate-brown crossbands on pale orange-brown ground colour.

Occasional individuals are plain brick red and have faintly indicated crossbands (Figure 1c); black spotting is restricted to the few anteriormost crossbands in the neck region.

The hemipenis in its everted state is deeply divided, each of the separate 'horns' terminating in a rounded, flattened cupula. The spermatic sulcus bifurcates at the point of division of the organ and extends onto both horns. The base of the organ is longitudinally ribbed, but the horns are conspicuously and uniformly spinose up to the terminal cupula. In its retracted condition, the hemipenis extends to just past the posterior margin of subcaudal 12. The organ and spermatic sulcus divide at the posterior margin of subcaudal 6 and the terminal cupula takes the appearance of a 'flounce'.

Details of Holotype

The holotype is in a poor state of preservation, especially in the posterior third of the body, and is badly faded. The tail tip including the caudal lure is missing. The following mensural and meristic data can be documented: SVI. 215; TailL 35 (incomplete); MBS 19; VTC 132; USC 29; temporals 3+3+5; preocular 1; suboculars and postcKulars 2. Indistinct cross bands are visible. The supralabials and temporals are extensively pigmented and the infralabials are prominently marked.
Figure 1 Photographs of various individuals of *Acanthophis wellsi* and *A. pyrrhus* from Western Australia, illustrating extent of inter- and intra-specific variation in morphology and colour pattern. Taxon and locality details as follows: a, *A. wellsi*, 'typical' colour phase from 26 km ENE Mardie Homestead (photograph B. Maryan); b, *A. wellsi*, 'melanistic' colour phase from Pannawonica (photograph B. Maryan); c, *A. wellsi*, 'weakly banded' colour phase from Pannawonica, WAM R113167 (photograph R.E. Johnstone); d, distinctive, pale form of *A. wellsi* from Yardie Creek, Cape Range Peninsula (photograph D. Knowles); e, *A. pyrrhus* from Ord Ranges (photograph B. Maryan); f, possible hybrid *A. wellsi* X *A. pyrrhus* from 4.5 km N Cane River (photograph B. Maryan).
Taxonomic remarks

Wells and Wellington (1985) evidently had some grounds for suspecting that the Pilbara adders were distinct from *A. pyrrhus*. However, they erred in their systematic treatment of the species on two counts. Firstly, *Acanthophis armstrongi* Wells and Wellington, 1985, proposed for adders of the "Pilbara and Kimberley regions of Western Australia", is a *nomen nudum* due to a lack of adequate diagnosis of the taxon (they refer to Storr's...
description and Figure 3 for diagnostic characters, yet Storr did not compare the Pilbara 'pyrrhus' with any other population of this species). And secondly, the proposed holotype of *A. armstrongi* (WAM R61537) is not an individual of the true Pilbara Adder, *A. wellsi*. In reality, it is either a true *A. pyrrhus*, as restricted herein, or an individual of hybrid origin. If the latter diagnosis is correct (see below for further discussion), then the name *armstrongi* would be additionally unavailable under the terms of Article 23h of the International Code for Zoological Nomenclature (3rd Edition, 1985), which states that animals of hybrid origin are not permissible as holotypes of new taxa.

Ball (1993: 5) reported the Pilbara Adders as a "suspected new species" and noted that taxonomic work was ongoing at the Western Australian Museum. Hoser (1997) initially applied the name "armstrongi" to the Pilbara Adders, but was subsequently informed that the Wells and Wellington name was based on an individual of *A. pyrrhus*. In describing *A. wellsi*, he erroneously implied that Aplin had decided against naming the Pilbara Adder (Hoser 1998: 38). The name *wellsi* only minimally satisfies the requirements of the ICZN (1985) but is adopted here in the interests of nomenclatural stability.

**Genetic comparisons**

The Pannawonica population of *A. wellsi* (WE1) consists of two 'typical' and four 'melanistic' phase individuals (Table 2). This sample does not show any differential assortment of alleles by colour phase and is consistent with a single population in Hardy-Weinberg equilibrium.

Table 3 shows the allelic profiles of 36 presumptive loci for eight *Acanthophis* populations and the four outgroup samples. The following loci were invariant: ENO, FBP, GPI, G3PDH, IDH-2, LAP, LDH-1, LDH-2, MDH-1, MDH-2, NDPK, PGK and TPI.

The single sample of *A. wellsi* from Cleaverville (WE2), on the northern margin of the species' distribution, shares all of its known alleles with the larger Pannawonica series, hence it can be regarded as part of the same population.

The single available sample of *A. pyrrhus* comes from near Yuendumu in the Northern Territory. It differs from the sample of *A. wellsi* in being homozygous for a distinct allele (c) at PepA, heterozygous with two distinct alleles (b,e) at PepB, and heterozygous with one shared (a) and one distinct (b) allele at Acoh-1.

The single available sample of *A. praelongus* (from northeastern Queensland) is somewhat better differentiated from *A. wellsi*. It is homozygous for distinct alleles at four loci (Aat-2, Ada, Est, Mpi), and is heterozygous with one shared and one distinct allele at each of Gda and Gpt.

The four populations of *A. antarcticus* are all well-differentiated from *A. wellsi*, but show considerable intraspecific variation (discussed further below). The *A. antarcticus* sample as a whole shows 'fixed' allelic differences from *A. wellsi* at two loci (Ada and Est), with other distinct alleles in various homozygous and heterozygous combinations at three others (Gpt, ldh-1 and Pgm-1). A similar level of distinction is observed from each of *A. pyrrhus* and *A. praelongus*. *Acanthophis pyrrhus* is distinct from *A. antarcticus* at Est and PepB, while *A. praelongus* is distinct from *A. antarcticus* at Aat-2 and Mpi. Not surprisingly, the larger sample of *A. antarcticus* also provides many unique alleles (e.g., at Acoh-2, Acyc, Gda, Gpt, ldh-1, PepD, Pgdh and Pgm-1).

The genetic data are summarised as a matrix of percent 'fixed' difference (i.e., loci which lack any shared alleles) in Table 4.

**Distribution and geographic variation**

*Acanthophis wellsi* is known from widely scattered localities throughout the Pilbara region, from Robe River and Pannawonica at the western end of the Hamersley Range to the Burrup Peninsula in the north and east through the Chichester Ranges to Carawine Gorge on the Oakover River (Figure 5). An apparently isolated population occurs on the Cape Range peninsula.
Unfortunately, sample sizes are inadequate to attempt any statistical analysis of geographic variation, owing to the confounding effect of sexual dimorphism. Specimens of *A. wellsii* from throughout the Pilbara region appear to be fairly uniform in size and meristic parameters. However, the sample of female specimens from the isolated Cape Range population (n=5; see Table 5) could be compared with that from the Pilbara region proper (n=10). This comparison demonstrates that the Cape Range population differs from that of the Pilbara in having significantly lower ventral counts and a relatively longer tail. The Cape Range specimens also differ from other *A. wellsii* in having distinctly
Table 4 Matrix of percent ‘fixed’ genetic difference between each of the species and populations. A genetic difference between two samples is regarded as ‘fixed’ if they lack any allele in common. The small samples available for analysis mean that many of the values will be an overestimate of the true level of ‘fixed’ genetic difference between the populations from which they are drawn.

<table>
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<th>WE2 (1)</th>
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<th>AN1 (1)</th>
<th>AN2 (2)</th>
<th>AN3 (2)</th>
<th>AN4 (1)</th>
<th>PR1 (1)</th>
<th>E1 (1)</th>
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<td>16 5</td>
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<td>10 5 10</td>
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<td>16 5</td>
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</tbody>
</table>

Table 5 Comparison of geographically discrete Pilbara and Cape Range populations of Acanthophis welsi. Statistical comparisons are limited to female samples due to small number of available males from the Cape Range population. Significant interpopulational differences are observed in ventral scale counts. The relative tail length values do not overlap between the two small samples, with Cape Range population females having proportionally longer tails. Mensural data are also presented for the combined sex sample of the Cape Range population.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pilbara - females</th>
<th>Cape Range - females</th>
<th>ANOVA results</th>
<th>Cape Range - both sexes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snout-vent Length</td>
<td>365.2 ± 65.0 (10)</td>
<td>324.7 ± 76.2 (3)</td>
<td>F = 0.839, df = 12, p = 0.379</td>
<td>301.6 ± 62.7 (8)</td>
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<tr>
<td></td>
<td>(254-443)</td>
<td>(237-375)</td>
<td></td>
<td>(237-375)</td>
</tr>
<tr>
<td>Tail Length</td>
<td>61.0 ± 13.69 (10)</td>
<td>66.7 ± 12.67 (3)</td>
<td>F = 0.462, df = 12, p = 0.536</td>
<td>63.4 ± 10.6 (5)</td>
</tr>
<tr>
<td></td>
<td>(41-77)</td>
<td>(53-78)</td>
<td></td>
<td>(53-78)</td>
</tr>
<tr>
<td>Total Length</td>
<td>426.2 ± 75.52 (10)</td>
<td>414.3 ± 85.07 (4)</td>
<td>F = 0.065, df = 13, p = 0.803</td>
<td>365.0 ± 72.0 (6)</td>
</tr>
<tr>
<td></td>
<td>(295-520)</td>
<td>(290-483)</td>
<td></td>
<td>(290-444)</td>
</tr>
<tr>
<td>Tail Length as% of total length</td>
<td>14.2 ± 1.24% (10)</td>
<td>17.2 ± 1.45% (3)</td>
<td>F = 57.95, df = 12, p = 0.008</td>
<td>17.5 ± 1.1% (5)</td>
</tr>
<tr>
<td></td>
<td>(11.5-15.5%)</td>
<td>(15.5-18.3%)</td>
<td></td>
<td>(15.5-18.3%)</td>
</tr>
<tr>
<td>Ventral body scales</td>
<td>137.2 ± 23.0 (10)</td>
<td>125.7 ± 2.31 (3)</td>
<td>F = 0.460, df = 9, p = 0.516</td>
<td>126.2 ± 1.9 (5)</td>
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<tr>
<td></td>
<td>(133-141)</td>
<td>(123-127)</td>
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<td>(123-128)</td>
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<tr>
<td>Subcaudal scales</td>
<td>46.0 ± 2.75 (5)</td>
<td>47.6 ± 4.51 (5)</td>
<td>F = 0.192, df = 14, p = 0.608</td>
<td>48.0 ± 4.2 (6)</td>
</tr>
<tr>
<td></td>
<td>(43-50)</td>
<td>(41-52)</td>
<td></td>
<td>(41-52)</td>
</tr>
<tr>
<td>Undivided subcaudal scales</td>
<td>22.5 ± 2.07 (10)</td>
<td>21.4 ± 6.19 (5)</td>
<td>F = 3.92, df = 14, p = 0.069</td>
<td>21.7 ± 5.6 (6)</td>
</tr>
<tr>
<td></td>
<td>(18-28)</td>
<td>(11-27)</td>
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<td>(11-27)</td>
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<tr>
<td>Divided subcaudal scales</td>
<td>22.5 ± 2.07 (10)</td>
<td>26.2 ± 5.31 (5)</td>
<td>F = 3.92, df = 14, p = 0.069</td>
<td>26.3 ± 4.8 (6)</td>
</tr>
<tr>
<td></td>
<td>(19-26)</td>
<td>(20-34)</td>
<td></td>
<td>(20-34)</td>
</tr>
<tr>
<td>Total body scales</td>
<td>183.0 ± 3.08 (5)</td>
<td>171.0 ± 2.65 (3)</td>
<td>F = 31.15, df = 7, p = 0.001</td>
<td>172.8 ± 4.1 (4)</td>
</tr>
<tr>
<td></td>
<td>(180-188)</td>
<td>(168-173)</td>
<td></td>
<td>(168-178)</td>
</tr>
</tbody>
</table>

flared supraocular scales (less pronounced than those of A. praelongus), more strongly developed dorsal keeling on scale rows 1–4, and in being considerably paler, with grey crossbands on a cream ground colour. One specimen (WAM R93212) from Vlaming Head at the extreme north end of the peninsula has bilaterally divided prefrontal scales, but without the associated strong keeling typical of A. pyrrhus. These differences suggest that the Cape Range population of A. welsi is genetically isolated from that of the Pilbara region, but the differences may also relate to differences in substrate between the two areas (limestone and sand vs iron-rich rocks and skeletal soils). The Cape Range population may warrant subspecific distinction from typical A. welsi; however, it would be prudent to first determine the level of genetic divergence between them.

Melanistic individuals are known from within each of the three sub-regions as defined above; i.e., from Mt Meharry in the southern Hamersley Range (WAM R67921); from Pannawonica on the
western margin of the Hamersley Range (n=7; e.g., WAM R113114, WAM R125735); and from Yandicoogina near the northest margin of the Pilbara uplands (WAM R78136). Additional localities include Millstream in the Fortescue River valley (animal photographed by David Robinson) and 60 km NNW of Newman in the Ophthalmia Range (roadkill sighting; Brian Bush, pers. comm.). The relative abundance of the melanistic form in any area is difficult to determine from voucher collections. Of the total sample of 13 specimens collected since 1991 from around Pannawonica, seven are melanistic individuals. However, this high percentage may well reflect collecting bias, as Ball (1993) reported a single melanistic individual out of 18 adders located during 6 hours of spotlighting along the Pannawonica Road on the night of 29 January 1993.

*Acanthophis pyrrhus* Boulenger, 1898

*Acanthophis pyrrhus* Boulenger, 1898: 75. (Type locality: Station Point, Northern Territorion).

*Acanthophis armstrongi* Wells and Wellington, 1985: 43. *Nomen nudum*. (Type locality: 3 km E Giralia, Western Australia).

Revised diagnosis

An elongate, slender-bodied *Acanthophis*, predominantly reddish in colour. Most similar to *A. welshii* in general appearance but differing from that species and all others in having prefrontal scales divided and strongly keeled, body scales with strong keeling extending down onto flanks and significantly higher ventral scale counts.

Further differs from *A. welshii* in having higher modal midbody scale count (21 vs 19), higher subcaudal scale counts, less prominent spotting of lower labial and mental scales and in details of hemipenial morphology (see below).

Further differs from *A. praehmgus* in lacking strong lateral flanges on the supraocular scales and in having lower modal midbody scale counts (21 vs 23).

Description

Summary mensural and meristic data are given in Table 6, together with results of statistical tests for sexual dimorphism.

SVL 160-622 (n=51). Mean SVL of adult males (404.0) and adult females (451.4) not significantly different. Tail. 31-118 (n=51); or 15.6-39.1% of Total Length; mean Tail. is not significantly different between males (89.6) and females (86.7).

Ventral scales 136-158 (n=52). Mean ventral scale counts of males (145.4) and females (144.1) not significantly different. Combined subcaudal count is 43-63 (n=44), mean subcaudal count significantly higher in males (59.0) than females (50.8). Undivided subcaudals 13-39 (n=53), mean USC significantly higher in males (32.0) than females (24.7). Divided subcaudals 15-37, mean DSC not differing between sexes. Caudal 'lure' dorso-ventrally expanded and compressed, and bearing more finely divided scales which project free of surface to impart a 'feathered' appearance. Tail tip most often dark (58%; n=33), but not uncommonly creamy white (27%) or banded (15.2%).

Body scales in 19-23 rows at midbody, modal 21 (81%; n=52). Upper six rows of body scales bear prominent keels; more lateral scale rows are weakly keeled or smooth.

Head oval-shaped, broadest posteriorly but not narrowing abruptly onto facial region (Figure 2a). Snout moderately depressed and elongate.

Head scales extremely rugose. Prefrontals invariably divided into lateral and medial scales. Supranasal, medial prefrontal, frontal and parietal scales with strong longitudinal ridging aligned in linear series. Lateral prefrontal scales with low ridge in alignment with keeled preocular. Single supraocular scale without lateral flange but with strong oblique ridge and other irregular sculpting. Preocular always single (n=56). Suboculars usually 2 (98%; n=50), rarely 3 (2%). Postoculars usually 2 (98%; n=50), rarely 3 (2%). Numerous temporal scales, usually arranged in 3+3+5, 3+4+5 pattern. Primary temporals always 3 (n=47). Secondary temporals 3 (66%; n=47) or 4 (34%). Tertiary temporals usually 5 (64%; n=47), less often 4 (33%), rarely 6 (3%). All but lowermost temporal scales bear distinct keels.

Rostral scale relatively low and broad. Upper labials always 6, fifth and sixth largest of series. 'Temporolabial' scale counted as part of secondary temporal series.

Main features of head and body pattern can be seen in Figures 1e and 2.

Body and tail are conspicuously banded in all specimens. Bands usually two scales in width (occasionally 1 or 3), colour alternating between pale brick-red/pale yellowish brown and darker reddish-brown/brown. Body usually with 43-47 dark bands, further 15 or so on tail. Conspicuous black spotting occurs across both anterior and posterior margins of dark bands along entire length of body and onto tail.

Crossbands become diffuse on lower flanks where they give way to two rows of black spots; these are most conspicuous on the neck and fade posteriorly onto the body. Ventral scales are immaculate.

The dorsum of the head is the same colour as the paler crossbands. Upper lip with extensive white zone extending onto lower temporal scales; posterior upper labials mottled with pale brick-red. Lower labials usually with poorly developed,
western Australian Death Adders

Table 6

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sex</th>
<th>N</th>
<th>Mean ± SD (Range)</th>
<th>ANOVA results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snout-Vent Length</td>
<td>M</td>
<td>10</td>
<td>398.5 ± 67.81 (302-498)</td>
<td>F = 3.60, df = 31, p = 0.067</td>
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<td></td>
<td>F</td>
<td>22</td>
<td>455.3 ± 82.63 (248-603)</td>
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<td>all</td>
<td>51</td>
<td>399.7 ± 121.05 (160-622)</td>
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<tr>
<td>Tail Length</td>
<td>M</td>
<td>10</td>
<td>87.9 ± 18.50 (65-115)</td>
<td>F = 0.0247, df = 31, p = 0.876</td>
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<tr>
<td></td>
<td>F</td>
<td>22</td>
<td>87.0 ± 11.97 (60-105)</td>
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<td>51</td>
<td>80.6 ± 23.23 (31-118)</td>
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<tr>
<td>Total Length</td>
<td>M</td>
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<td>499.0 ± 79.69 (386-613)</td>
<td>F = 1.366, df = 23, p = 0.255</td>
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<td>F</td>
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<td>545.1 ± 100.51 (345-708)</td>
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<td>all</td>
<td>42</td>
<td>472.7 ± 151.42 (345-708)</td>
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<td>Tail Length as% of Total Length</td>
<td>M</td>
<td>9</td>
<td>17.9 ± 1.40</td>
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<tr>
<td></td>
<td>F</td>
<td>15</td>
<td>16.5 ± 5.29</td>
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<td>all</td>
<td>42</td>
<td>20.5 ± 3.63 (15.6-39.1)</td>
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<td>Ventral body scales</td>
<td>M</td>
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<td>145.2 ± 4.69 (137-152)</td>
<td>F = 0.011, df = 32, p = 0.918</td>
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<tr>
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<td>F</td>
<td>21</td>
<td>145.0 ± 4.36 (139-158)</td>
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<td>all</td>
<td>52</td>
<td>145.2 ± 4.14 (136-158)</td>
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<tr>
<td>Subcaudal scales</td>
<td>M</td>
<td>9</td>
<td>59.0 ± 1.87 (57-62)</td>
<td>F = 41.33, df = 19, p = 0.000</td>
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<td>F</td>
<td>11</td>
<td>50.2 ± 3.74 (43-57)</td>
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<td>37</td>
<td>53.7 ± 5.03 (43-63)</td>
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<td>Undivided subcaudal scales</td>
<td>M</td>
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<td>31.1 ± 3.81 (27-39)</td>
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</tr>
<tr>
<td></td>
<td>F</td>
<td>21</td>
<td>24.0 ± 6.12 (13-38)</td>
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<td>all</td>
<td>47</td>
<td>25.9 ± 6.07 (13-39)</td>
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</tr>
<tr>
<td>Divided subcaudal scales</td>
<td>M</td>
<td>9</td>
<td>27.4 ± 2.88 (23-31)</td>
<td>F = 0.031, df = 25, p = 0.861</td>
</tr>
<tr>
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<td>F</td>
<td>17</td>
<td>27.8 ± 6.05 (15-37)</td>
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</tr>
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<td>all</td>
<td>44</td>
<td>27.6 ± 4.74 (15-37)</td>
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</tr>
<tr>
<td>Total ventral scales</td>
<td>M</td>
<td>9</td>
<td>204.3 ± 6.44 (194-213)</td>
<td>F = 9.422, df = 19, p = 0.006</td>
</tr>
<tr>
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<td>F</td>
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<td>193.8 ± 8.45 (182-215)</td>
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<td>all</td>
<td>33</td>
<td>199.5 ± 8.27 (182-215)</td>
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</tr>
</tbody>
</table>

centrally located 'spots' of same pale brick-red colour, but these are absent in some individuals. Mental scale and adjacent chinshields are usually immaculate but have an indistinct, inverted-V mark in some specimens.

No everted hemipenes of *A. pyrrhus* were available for study. Dissection of one individual (WAM R79008) revealed that the inverted organ divides at the level of subcaudal 8 and extends back to subcaudal 12. The spermatic sulcus divides at subcaudal 7, below the point of separation of the horns. The basal portion of the hemipenis is longitudinally ribbed and lacks spines. The spinose zone commences just below the hemipenial bifurcation and continues onto the separate horns. The spines are largest proximally and reduce in size towards the tips of the horns. The terminal part of both horns is smooth save for some weak longitudinal ribbing; i.e., it appears to lack the conspicuous terminal flounce (cupula) seen in *A. wellsi*.

**Taxonomic remarks**

The type specimen of *Acanthophis pyrrhus* (BMNH 1946.1.18.62) was not examined during this study. However, Boulenger's (1898) description mentions all of the key diagnostic features of the larger sample documented here. These include the rugose head-shields, divided prefrontals, midbody scales in 21 rows, and a high number of ventral (146) and subcaudal (50) scales. A lack of spotting on the lower labials and throat can also be inferred from his description.

For sake of completeness, we have listed *Acanthophis armstrongi* Wells and Wellington, 1985 as a junior synonym of *A. pyrrhus*. However, as indicated earlier, this is a *nomen nudum* and thus has no nomenclatural standing. As will be discussed at greater length below, this specimen is also quite possibly of hybrid origin.

Hoser (1998: 35) made inappropriate use of the unavailable name *armstrongi* Wells and Wellington to taxonomically distinguish populations of *A. pyrrhus* from “the Great Sandy Desert of WA and adjacent areas, including coastal parts of the Pilbara”. He noted that specimens of *A. pyrrhus* from this area “appear to have more yellow colouring dorsally than those seen from Central
Australia", but qualified this observation by noting "whether this is a general trend difference between both forms is not yet known" (Hoser 1998: 36). As indicated below, the present analysis does not support subspecific distinction between northwestern and Central Australian populations of *A. pyrrhus*.

**Distribution and geographic variation**

Widely distributed throughout central and western Australia (Figure 3), from southwestern Queensland (Ingram and Raven 1991) through Central Australia north to Barrow Creek, south to the Everard Ranges and west to Balgo Mission and Gahnda Rockhole. In northwestern Australia it occurs in coastal plain habitats from the Port Hedland area along the Eighty Mile Beach to Broome and east to "Wynne Creek" on the northern margin of the Great Sandy Desert (Figure 4). In southern Australia it is known only from Ooldea on the northeastern margin of the Nullarbor Plain. In southwestern Australia it is recorded from scattered points between Kalgoorlie and Albion Downs Homestead in the eastern Goldfields, to Wurarg and Bunjil in the northern Wheatbelt and north to Middalya Homestead, close to the southern border of Exmouth Gulf.

Geographic variation within *A. pyrrhus* was investigated by dividing the total sample into three subpopulations, based on the major physiographic clustering of localities: 1) a northwestern group; 2) a central Australian group; and 3) a southwestern group. Mensural and meristic data for each of these subpopulations are compared in Table 7. The most striking contrast is between the northwestern and southwestern populations which show significant

![Figure 3](image-url)  
*Figure 3* Map showing broad distribution of *A. wellsii* and *A. pyrrhus*, not including possible hybrids.
Western Australian Death Adders

Figure 4 Map showing detailed distribution of *A. wellsi* and *A. pyrrhus* in northwestern Australia, including specimens of possible hybrid origin.

differences in both ventral and subcaudal counts (both higher in northwestern animals). However, values for the Central Australian population are intermediate between the two, suggesting the possibility of a cline from north to south via Central Australia. As might be expected on more general zoogeographic and physiographic grounds, SAM R1106 from Ooldea is consistent with the southwestern population of *A. pyrrhus* in its relatively low ventral and subcaudal counts (142 and 49, respectively).

Four adult female specimens from Durrie Station in southwestern Queensland have ventral counts of 127–143 which are relatively low in comparison with the Central Australian female sample (139–144, n=6). However, these specimens are consistent in all other respects with typical *A. pyrrhus*.

Possible hybrid populations – *A. wellsi X A. pyrrhus*?

The most compelling evidence of hybridization between *A. wellsi* and *A. pyrrhus* comes from the country between the Pilbara region and the Cape Range Peninsula (Figure 4). This zone of low-lying, sandy habitats has produced a total of nine *Acanthophis* specimens, the majority coming from around Cane River Homestead (Table 8). One of the Cane River specimens (WAM R80442) appears to be indistinguishable in all respects from Pilbara region *A. wellsi*. In contrast, all of the remaining specimens show an admixture of *wellsi*-like and *pyrrhus*-like features, and several show abnormal features of varying degrees of severity. WAM R80430 is very close to typical *A. wellsi* but is unusual in having a partial division of the parietal
Table 7 Summary mensural and meristic data for each of three regional populations of *Acanthophis pyrrhus*. Data are presented for males only for most parameters, but additionally for a combined sample (both sexes + juveniles) for ventral scale count which does not exhibit sexual dimorphism. The results of One-way ANOVA (F values and statistical significance) are shown for each parameter. The northern population has significantly higher ventral scale counts than the southern population, with the central population intermediate between these. Regional samples are defined as follows: Northern = northern WA, north of the Pilbara ranges; Central = central Australia; Southern = southern WA, south of the Pilbara and central Australian ranges.

<table>
<thead>
<tr>
<th>MALES ONLY</th>
<th>Northern</th>
<th>Central</th>
<th>Southern</th>
<th>ANOVA results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snout-vent Length</td>
<td>439.0 ± 25.46 (2)</td>
<td>437.5 ± 83.54 (13)</td>
<td>491.5 ± 94.04 (6)</td>
<td>F = 0.87, df = 20, p = 0.436</td>
</tr>
<tr>
<td>Tail Length</td>
<td>90.0 ± 22.21 (2)</td>
<td>83.8 ± 12.24 (13)</td>
<td>92.5 ± 12.03 (6)</td>
<td>F = 1.10, df = 20, p = 0.351</td>
</tr>
<tr>
<td>Total Length</td>
<td>529.0 ± 46.67 (2)</td>
<td>563.0 ± 110.28 (6)</td>
<td>584.0 ± 105.98 (6)</td>
<td>F = 0.915, df = 13, p = 0.429,</td>
</tr>
<tr>
<td>Tail Length as % of total length</td>
<td>17.0 ± 2.83% (2)</td>
<td>14.7 ± 1.12 (6)</td>
<td>16.2 ± 0.98% (6)</td>
<td>F = 18.80, df = 19, p = 0.000</td>
</tr>
<tr>
<td>Ventral body scales</td>
<td>158 (1)</td>
<td>145.9 ± 2.82 (13)</td>
<td>141.3 ± 2.07 (6)</td>
<td>F = 18.80, df = 19, p = 0.000</td>
</tr>
<tr>
<td>Subcaudal scales</td>
<td>57 (1)</td>
<td>50.0 ± 2.65 (47-52)</td>
<td>49.2 ± 3.82 (6)</td>
<td>F = 2.13, df = 9, p = 0.189</td>
</tr>
<tr>
<td>Undivided subcaudal scales</td>
<td>26 (1)</td>
<td>24.2 ± 6.67 (13)</td>
<td>23.2 ± 6.68 (6)</td>
<td>F = 0.967, df = 19, p = 0.908</td>
</tr>
<tr>
<td>Divided subcaudal scales</td>
<td>31 (1)</td>
<td>28.9 ± 4.73 (9)</td>
<td>26.0 ± 8.53 (6)</td>
<td>F = 0.459, df = 15, p = 0.629</td>
</tr>
<tr>
<td>Total body scales</td>
<td>215 (1)</td>
<td>193.7 ± 4.16 (3)</td>
<td>190.5 ± 5.72 (6)</td>
<td>F = 9.09, df = 1, p = 0.011</td>
</tr>
<tr>
<td>COMBINED SAMPLE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventral body scales</td>
<td>147.1 ± 4.63 (22)</td>
<td>144.8 ± 3.40(19)</td>
<td>142.4 ± 2.12 (10)</td>
<td>F= 5.77, df = 50, p = 0.005</td>
</tr>
</tbody>
</table>

Table 8 Measurements, meristics and morphological data for nine possible hybrid individuals (*A. welsi* X *A. pyrrhus*) from the Cane River – Giralia region.

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>R80430</th>
<th>R80431</th>
<th>R80432</th>
<th>R80433</th>
<th>R80437</th>
<th>R80442</th>
<th>R80443</th>
<th>R61357</th>
<th>R71228</th>
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<tbody>
<tr>
<td>Sex</td>
<td>F</td>
<td>M</td>
<td>M</td>
<td>F</td>
<td>F</td>
<td>M</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Snout-Vent Length</td>
<td>198</td>
<td>347</td>
<td>355</td>
<td>418</td>
<td>175</td>
<td>263</td>
<td>324</td>
<td>634</td>
<td>364</td>
</tr>
<tr>
<td>Tail Length</td>
<td>31</td>
<td>60</td>
<td>57</td>
<td>52</td>
<td>30</td>
<td>43</td>
<td>50</td>
<td>91</td>
<td>66</td>
</tr>
<tr>
<td>Total Length</td>
<td>229</td>
<td>407</td>
<td>412</td>
<td>470</td>
<td>205</td>
<td>306</td>
<td>374</td>
<td>725</td>
<td>430</td>
</tr>
<tr>
<td>Tail as% of Total Length</td>
<td>13.5</td>
<td>14.7</td>
<td>13.8</td>
<td>11.1</td>
<td>14.6</td>
<td>14.1</td>
<td>13.4</td>
<td>12.6</td>
<td>15.4</td>
</tr>
<tr>
<td>Ventral body scales</td>
<td>140</td>
<td>131</td>
<td>132</td>
<td>144</td>
<td>138</td>
<td>138</td>
<td>140</td>
<td>143</td>
<td>143</td>
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<tr>
<td>Total subcaudal scales</td>
<td>49</td>
<td>49</td>
<td>47</td>
<td>47</td>
<td>35</td>
<td>39</td>
<td>48</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Undivided subcaudals</td>
<td>24</td>
<td>26</td>
<td>30</td>
<td>25</td>
<td>37</td>
<td>25</td>
<td>25</td>
<td>29</td>
<td>32</td>
</tr>
<tr>
<td>Divided subcaudals</td>
<td>25</td>
<td>23</td>
<td>17</td>
<td>17</td>
<td>16</td>
<td>24</td>
<td>23</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Total ventral scales</td>
<td>189</td>
<td>180</td>
<td>179</td>
<td>179</td>
<td>191</td>
<td>187</td>
<td>188</td>
<td>193</td>
<td>193</td>
</tr>
<tr>
<td>Mid-body scale rows</td>
<td>20</td>
<td>19</td>
<td>19</td>
<td>20</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Number of prefrontals</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Lateral scales keeled</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Labial scales spotted</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Figure 5 UPGMA dendrogram based on matrix of % genetic fixed differences between various populations and individuals of *Acanthophis* and the outgroup taxa *Echiopsis curta* and *Notechis* spp.

prefrontals and strong body keeling which extends well down the flanks. This specimen also shows several other abnormal features, namely a transversely divided frontal scale, a posteriorly fragmented parietal scale, loss of the right preocular scale and a bulging right eye.

WAM R61357 from 3 km E of Giralia was figured by Storr (1981) as a typical example of *A. pyrrhus*, and later designated by Wells and Wellington (1985) as the holotype of *Acanthophis armstrongi* (see earlier comments regarding the status of this taxon). This specimen shows a predominance of features normally associated with *A. pyrrhus*, including extensive keeling of body scales, 21 midbody scale rows, a high ventral count (143) and an oval-shaped head with white upper lip. However, the presence of an undivided prefrontal on one side and the absence of black spotting across the rear of the dark cross-bands are suggestive of an influence, albeit a weak one, from *A. wellsi*. The geographic proximity to other populations showing anomalous scale developments and unusual, 'intermediate' morphologies, also gives cause for doubt concerning the status of this specimen. For the present, WAM R61357 is perhaps best treated with the Cane River series as a potential hybrid or backcross animal.

WAM R71228 from Mia Mia (east of Giralia) is also similar to *A. pyrrhus* in having strongly keeled body scales, 21 midbody scale rows, high ventral (143) and subcaudal (50) counts, an oval-shaped head with white upper lip and rugose frontonasal, prefrontal and frontal scales. However, its prefrontal scales are undivided, unlike any specimen of *A. pyrrhus* away from this zone of potential hybridization.

Another possible hybrid individual from this general area is currently held in captivity by Mr Brad Maryan of Perth (Figure 1f). This specimen, from 4.5 km NW of Cane River, has undivided, weakly keeled prefrontal scales like *A. wellsi*, but shows strong and laterally extensive keeling of the body scales as well as a 'pyrrhus'-like body pattern with black spotting across both the anterior and posterior margins of the dark cross-bands.

The high incidence of abnormalities and morphological intermediates in the Giralia-Cane River area is consistent with the presence of a contemporary 'hybrid swarm' between *A. wellsi* and *A. pyrrhus*. Theoretically, the 'Giralia-Cane River' series might include both F1 hybrids and backcross individuals in varying combinations, and thus be of diverse genetic parentage. However, alternatives to the 'hybrid swarm' hypothesis are not difficult to find (e.g., phenotypic instability in marginal habitat), and it would be prudent to regard this as
no more than a working hypothesis until such time as it can be fully documented through analysis of appropriate biochemical markers.

Away from the Giralia-Cane River area, the morphology of both A. wellsi and A. pyrrhus is extremely conservative, with very low incidence of scale or pattern anomalies. As noted earlier, one exception is WAM R93212 from Vlaming Head, at the extreme northern end of the Cape Range peninsula, which has divided but unkeeled prefrontals. However, since A. pyrrhus is not known to occur anywhere on the peninsula, this anomaly must either be an expression of natural variation within A. wellsi, or else, an indicator of past interspecific interaction, perhaps in Pleistocene or early Holocene times when lowered sea levels might have created more extensive coastal plain habitats for A. pyrrhus.

A second example of prefrontal division within A. wellsi is provided by WAM R78136 from Yandicoogina, on the far eastern margin of the Pilbara uplands. This specimen shows unilateral division of the left prefrontal scale, but displays no other similarities to A. pyrrhus. The closest record of the later species is from "Mt Wyne" on the northern side of the Great Sandy Desert (WAM R2138). Nevertheless it is of interest to note that the Yandicoogina record also falls on the periphery of the range of A. wellsi, in an area where interaction with A. pyrrhus might be expected to occur.

Interspecific relationships

Successful analysis of interspecific relationships within any group generally hinges on the identification of meaningful ‘outgroup’ taxa which, for phenetic analyses, provide a sense of ‘scale’ for ingroup evolution, and for cladistic analyses, provide a basis for identification of character ‘polarity’ i.e., the direction that evolution has taken within the group. In the past, Acauthophis has generally been regarded as an isolated genus, without any especially close relatives. Recent genetic, immunological and morphological work on Australian elapids (Mengden 1985; Schwane & al. 1985; Shine 1985) has indicated that its affinities probably lie among the dozen or so genera of terrestrial live-bearing elapids, most of which also possess an undivided anal scale and at least some undivided subcaudal scales. Among these taxa, the closest affinity may be with the monotypic genus Echiopsis, which shares an increased number of temporal scales with Acauthophis (Greer 1998: 188), along with a similar venom structure (Marshall and Hermann 1984; Marshall 1985). However, the results of the limited genetic analysis reported here suggest that Echiopsis curta and Acauthophis spp. are not especially close relatives, with the former being closer genetically to Notechis spp. For the present, it would thus seem unwise to employ any one particular elapid genus as an immediate outgroup to Acauthophis. Other potential sister taxa for Acauthophis include the species of Denisonia (seus Cogger 1996; i.e., desii, maculata) which are similar in various aspects of morphology (stocky body-form, broad headed, barred patterning of the upper lips, low number of ventral and subcaudal scales, cross-banding in D. desii) and in behavioural characteristics (cryptozoic; nocturnal; flattened, rigid defensive posture).

Despite the methodological limitation imposed by uncertain outgroup relations, the genetic and morphological data provide some insights into the pattern of evolution within the genus Acauthophis. These data are discussed separately so as to clearly distinguish between the contribution of each kind of evidence. This contrasts with the ‘total evidence’ approach (e.g., Kluge 1989), which in the present case would undoubtedly provide a more fully resolved cladogram but one of doubtful validity.

Genetic characters

The limited genetic data have been analysed using both phenetic and cladistic methodologies [see Richardson et al. (1986) for discussion of analytical methods]. Although the results are based on very small numbers of individuals, they are nonetheless informative of general patterns and further serve to highlight areas in need of closer examination.

The broad pattern of intra- and inter-specific genetic comparisons was explored by an UPGMA based on the matrix of percent fixed allelic differences (i.e., proportion of loci at which two individuals fail to share any allele). The resultant dendrogram is shown in Figure 5. As anticipated, A. wellsi is phenetically closest to A. pyrrhus, while A. antarcticus and A. praelongus are approximately equidistant from each other and from the A. wellsi - A. pyrrhus couplet. The four populations of A. antarcticus form a discrete cluster on the dendrogram but show considerable intraspecific variation. Closer examination of this widespread southern and eastern Australian taxon is obviously warranted.

The various Notechis and Echiopsis individuals are genetically far more divergent from each of the Acauthophis species, with fixed allelic differences at around 50% of all loci. The two samples of Notechis, each representing different species, differ at five loci (Ca, Gpt, Gsr-1, PepB and Pgm-1) and thus show approximately the same level of divergence as A. wellsi and A. antarcticus. The Notechis species show fixed differences with Echiopsis curta at seven loci (Aat-1, Acoh-1, Acoh-2, Ada, Gsr-1, Lgl and PepB). The two specimens of L. curta share alleles at all loci, pointing to a low level of genetic differentiation between eastern and western populations of this species.

For the cladistic analysis, Echiopsis curta and the
two Notechis species were employed as outgroup taxa. Eleven loci contain variation of cladistic significance (including autapomorphies). Each of the species of Acanthophis has at least one uniquely derived allele. In contrast, evidence of interspecific relationships is ambiguous, with one potential synapomorphy observed between A. wellsi and each of A. pyrrhus (Estb) and A. praelongus (Pgdb). No derived alleles are shared between these latter two species or between A. antarcticus and any other taxon.

Among the outgroup taxa, one unique allele (Ac01-19) is shared by the Notechis species, while Echiopsis curia has a total of eight unique alleles. The species of Echiopsis and Notechis also share many alleles not detected in any Acanthophis species; however, under the outgroup method these alleles cannot be assigned any polarity.

**Morphological characters**

The various species of Acanthophis differ from each other in a combination of meristic 'shifts' and minor morphological features. Without delving into internal anatomy, the number of characters available for cladistic analysis is thus relatively small, negating the need for any quantitative analysis.

Table 9 lists the character states for each of eight characters which serve to distinguish among the various species of Acanthophis. The evolutionary polarity of certain of these characters has been discussed by Wallach (1985) on the basis of a comprehensive survey of Australian and a selection of non-Australian elapids. His observations will be tempered here with observations on the condition in the group of terrestrial live-bearing elapids with which Acanthophis is generally associated.

**Character 1. Midbody scale rows:** Wallach (1985) considers values between 19–21 to be plesiomorphic for elapids. Within Acanthophis the lowest values are found in A. wellsi (mode 19) and the highest in A. praelongus (mode 23). Values of 15–19 are common among terrestrial live-bearing elapids. We regard 19 midbody scales as the ancestral value and higher values as derived within Acanthophis.

**Character 2. Ventral scale number:** Wallach (1985) considers values between 19–21 to be plesiomorphic for elapids in general (Wallach 1985); subcaudal counts for Acanthophis fall at the bottom end of this range, while values for most other terrestrial live-bearers are somewhat lower again. The various Acanthophis species differ only slightly from one another in subcaudal counts; the mean value is highest in A. pyrrhus and lowest in A. antarcticus and A. wellsi. The high subcaudal count of A. pyrrhus is partly a consequence of its relatively longer tail (see Character 4), but also reflects the more finely scaled and elaborate nature of its caudal lure. In A. wellsi the caudal lure is less specialized in shape and aspects of scalation, but is more often set off from the remainder of the tail by its white or cream colouration. The caudal lure of A. praelongus is similar to that of A. wellsi, while that of A. antarcticus tends to be deeper and flattened, but without the 'feathered' scalation of A. pyrrhus.

**Character 3. Subcaudal scale number:** Values of around 50–70 are probably ancestral for elapids in general (Wallach 1985); subcaudal counts for Acanthophis fall at the bottom end of this range, while values for most other terrestrial live-bearers are somewhat lower again. The various Acanthophis species differ only slightly from one another in subcaudal counts; the mean value is highest in A. pyrrhus and lowest in A. antarcticus and A. wellsi. The high subcaudal count of A. pyrrhus is partly a consequence of its relatively longer tail (see Character 4), but also reflects the more finely scaled and elaborate nature of its caudal lure. In A. wellsi the caudal lure is less specialized in shape and aspects of scalation, but is more often set off from the remainder of the tail by its white or cream colouration. The caudal lure of A. praelongus is similar to that of A. wellsi, while that of A. antarcticus tends to be deeper and flattened, but without the 'feathered' scalation of A. pyrrhus.

**Character 4. Relative tail length:** Wallach (1985) cites a relative tail length of 15–20% as the likely ancestral state for this character.

### Table 9

<table>
<thead>
<tr>
<th>Character</th>
<th>A. wellsi</th>
<th>A. antarcticus</th>
<th>A. praelongus</th>
<th>A. pyrrhus</th>
<th>Ancestral state in genus</th>
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</thead>
<tbody>
<tr>
<td>1. Midbody scale rows</td>
<td>19</td>
<td>21</td>
<td>23</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>2. No. ventral scales</td>
<td>134</td>
<td>119</td>
<td>129</td>
<td>145</td>
<td>130–145</td>
</tr>
<tr>
<td>3. No. subcaudal scales</td>
<td>47</td>
<td>46</td>
<td>51</td>
<td>53</td>
<td>45–50</td>
</tr>
<tr>
<td>4. Rel. tail length</td>
<td>15.8%</td>
<td>20.6%</td>
<td>22.2%</td>
<td>20.5%</td>
<td>15–20%</td>
</tr>
<tr>
<td>5. Lateral scale keeling</td>
<td>weak</td>
<td>weak</td>
<td>weak</td>
<td>strong</td>
<td>weak</td>
</tr>
<tr>
<td>6. Head scale rugosity</td>
<td>weak</td>
<td>weak</td>
<td>moderate</td>
<td>strong</td>
<td>weak</td>
</tr>
<tr>
<td>7. Prefrontal scales</td>
<td>entire</td>
<td>entire</td>
<td>entire</td>
<td>divided</td>
<td>entire</td>
</tr>
<tr>
<td>8. Lip pattern</td>
<td>barred</td>
<td>barred</td>
<td>barred</td>
<td>unbarred</td>
<td>barred?</td>
</tr>
</tbody>
</table>
ancestor condition. Values for *Acanthophis* species and for most other terrestrial live-bearers fall within this range. The tail is relatively shortest in *A. wellsii* and longest in *A. praelongus*. It is interesting to note that interspecific trends in tail length do not match those in subcaudal counts, indicating that the two variables are not strictly correlated.

**Character 5. Body scale keeling** Keeling of body scales is an unquestionably derived feature (Wallach 1985). Although all *Acanthophis* species show scale keeling along the dorsum, this is strongly developed and also laterally extensive only in *A. pyrrhus*. Keeling of body scales is found among many arid-adapted squamates, but is also characteristic of various groups of water snakes; it is presumably of diverse functional and/or physiological significance.

**Character 6. Condition of prefrontal scales** These are almost always entire among elapid snakes. Within *Acanthophis*, the alternative condition of divided prefrontal scales is characteristic for *A. pyrrhus* and occurs as a not uncommon variant in *A. antarcticus* (Storr 1981). It is unquestionably a derived character state which may serve to link *A. pyrrhus* to *A. antarcticus*.

**Character 7. Head scale rugosity** The head scales are smooth in the great majority of elapid snakes. Although some sculpting of the head scales is present in all *Acanthophis* species, this feature is taken to its extreme in *A. pyrrhus* in which many of the major head shields bear one or more major ridges. Subdivision of the prefrontal scale in this species might be related to this phenomenon, as the prefrontal scales bear especially strong longitudinal keels. On the other hand, occasional subdivision of the prefrontal scale is also observed in *A. antarcticus*, which lacks such pronounced keeling.

**Character 8. Lip patterning** The upper lip and buccal floor are boldly marked in all *Acanthophis* species except *A. pyrrhus* in which these areas are faintly marked or immaculate. Similar marking is present in various other elapid species, although some closely-related *Denisonia* spp. and we are therefore inclined to view the condition in *A. pyrrhus* as the more derived one.

Overall, *A. wellsii* emerges from this admittedly limited morphological analysis as potentially the most plesiomorphic living member of the genus. This is particularly evident in its very low midbody count but also in its lack of apparent specialization in any of the considered features. *Acanthophis praelongus* differs from this ancestral form only in having an increased number of scale rows (MBS to a mode of 23) and a slight increase in the number of subcaudal scales.

*Acanthophis antarcticus* and *A. pyrrhus* are both significantly more derived, although each has diverged in quite different evolutionary directions. In the case of *A. antarcticus*, the trend has been towards increased stoutness, with an increase in scale rows (MBS to mode of 21) and a reduction in ventral scale number. In *A. pyrrhus*, a similar increase in scale series (MBS to mode of 21) is combined with a marked increase in ventral scale number and a more slender body form. Observation of captive specimens of *A. pyrrhus* and *A. wellsii* indicates that both of these species are considerably more mobile and agile than the heavier-bodied, stockier *A. antarcticus*. Whether *A. pyrrhus* in particular exhibits a greater degree of mobility or even arboreality is a question that can only be answered through further ecological and behavioural study of these poorly known species.

Additional to the changes in body proportion, *A. pyrrhus* has also become exceptionally rugose, with extensive body keeling and heavily sculpted head scalation. Subdivision of the prefrontal scales, a highly diagnostic feature of this species, may also be related to this increased irregularity of all scale surfaces. One final feature of note about *A. pyrrhus* is the apparently derived loss of bold patterning from the upper lip and buccal floor; the significance of this development is obscure.

**DISCUSSION**

The Pilbara Adder, *Acanthophis wellsii* is readily distinguished on morphological criteria from each of the other currently recognised species of *Acanthophis*. This is particularly so in the case of *A. pyrrhus*, the Desert Adder, with which *A. wellsii* was formerly confused. With its elongate body and excessively rugose head and body scales, *A. pyrrhus* is in many ways the most specialised member of the genus and it is clearly well-adapted to life in some of Australia's harshest environments - the sand and stony deserts of the major sedimentary basins. The fact that the Pilbara Adder lacks an equivalent degree of morphological specialisation, despite the fact that it occurs in an equally harsh climatic zone, probably indicates a greater reliance on behavioural specialisations, especially the use of cooler microhabitats among and under rocks and in sheltered gullies.

*Acanthophis wellsii* is closest in overall morphology to *A. praelongus*. However, it is readily distinguishable from this species on combinations of meristic values (especially the elevated MBS of the latter) and aspects of colouration. Cladistic analysis of morphological variation within the genus suggests that the general similarity between these two species is most likely due to the common retention of ancestral features.

The presence of these two relatively plesiomorphic species in northern Australia suggests a possible place of origin for the genus in
that region. Interestingly enough, this would be away from the modern geographic centre of diversity of the terrestrial live-bearers, the majority of which are found in southern and eastern Australia (Shine 1985). However, the presence of other members of this group (e.g., Denisonia deinsi, Parasuta spp., Suta spp.) in both inland and northern Australia cautions against any simplistic interpretation of these distributional patterns.

To date, there has been no recorded instance of sympatry between two species of Acantophis and it has thus not been possible to examine the extent of reproductive isolation between congeners (i.e., to apply the ‘biological species’ concept). Instead, recognition of the various morphological entities as species must rely on some other criterion, such as the ‘phylogenetic species’ concept with its emphasis on the historical individuality of taxa (see Baum (1992) for an introduction to this literature; and Frost and Hillis (1990) for some herptological examples).

The limited genetic data available indicate that each of the four Acantophis species does indeed represent a discrete evolutionary lineage, albeit within a close knit evolutionary unit. Phenetic analysis of the data suggests that the two most arid-adapted species, A. welsi and A. pyrrhus, are sibling-taxon within the genus. However, cladistic analysis of the data fails to provide unambiguous support for a welsi-pyrrhus clade, but suggests alternative cladistic links between A. welsi and each of A. pyrrhus and A. praelongus. The genetic evidence for interspecific afinsities is thus inconclusive.

Storr (1981) suggested that the various forms of Acantophis could be treated tentatively as ‘allospecies’ (i.e., weakly differentiated taxa which have originated through allopatric speciation, sensu Mayr 1959). The relatively small genetic distances observed between each of the four species of Acantophis would appear to support Storr’s view. However, in this context it is worth noting that the genetic data are seemingly in conflict with immunological data presented by Schwaner et al. (1985) based on Microcompliment Fixation of transferrin. These data show quite large molecular distances between antigens for each of A. praelongus and A. pyrrhus and an antisem for A. antarcticus [23 and 14 units respectively; compared with 25-47 units (most values > 30) between Acantophis and other genera of Australian elapidts. The explanation for this discrepancy presumably relates to variable rates of molecular vs. genic evolution, but in this instance it is not clear which one is slow and which is fast.

Storr (1981) also remarked on the apparent lack of evidence for ‘gene flow’ between the various species of Acantophis. From the more detailed analysis presented here, it appears likely that A. welsi and A. pyrrhus do in fact hydridise where their geographic ranges abut. The strongest evidence for this comes from the area between Giralia and Onslow where a population of A. pyrrhus appears to intrude between the Pilbara and Cape Range populations of A. welsi. Specimens from this area show an admixture of normally distinct species characteristics, together with a high incidence of scale and other abnormalities. This evidence is highly suggestive of hybridization; however, more detailed investigation including genetic analysis is required to determine the nature and extent of the interaction. A captive breeding program currently underway in collaboration with members of the Western Australian Society of Amateur Herpetologists will hopefully also shed light on the potential for hybridization between these and other species of Acantophis.

The presence of partially melanistic individuals within some populations of A. welsi is significant in view of the growing literature on colour and pattern polymorphism among snakes and other reptiles (Vinegar 1974; Bechtel 1978; Wolf and Werner 1994). Captive cross-breeding experiments currently underway may help determine to underlying genetic basis of this variation (cf., Zweifel 1981).

However, field studies of A. welsi will be necessary in order to understand the full significance of pattern polymorphism in the ecology and population dynamics of this inhabitant of a complex, arid-zone environment.

ACKNOWLEDGEMENTS

This project was initiated upon receipt of some unusual Adders from Pannawonica, courtesy of Lori Gane, then of Pannawonica, and Peter Kendrick, Department of Conservation and Land Management, Karratha. Mark Cowan and Nadine Guthrie of the Western Australian Museum performed many of the scale counts for this study. Doug Elford of the Western Australian Museum took the photographs of preserved specimens.

Our special thanks go to the many Western Australian amateur herpetologists who have made a significant contribution to the study of Acantophis over the last five years, most notably Simon Ball, Brian Bush, Lori Gane, Brad Maryan, David Robinson and Cherie Sutherland.

REFERENCES


Appendix: Lists of Material Examined

Material included in morphological analysis

*Acanthophis wellsi*

Burrup Peninsula (20°36'S, 116°48'E): WAM R84284; 10 km S Cleaverly (20°45'S, 117°00'E); WAM R11442708; 10 km NE of Balmoral (21°06'S, 116°14'E); WAM R75003; Marble Bar (21°10'S, 119°44'E); WAM R438, 12671, 14061 and 12672 (10 km N); Mardie Stn (21°11'S, 115°59'E); WAM R13873, WAM R26822; Mardi Road House (21°18'S, 116°08'E); WAM R81838; Mt Herbert (21°20'S, 117°13'E); WAM R20239; Carawine Gorge Station (21°37'S, 118°57'E); WAM R116°14'E); WAM R75003; Marble Bar (21°08'S, 116°19'E); WAM R8318; Vlaming Head Lighthouse (21°48'S, 116°13'E); WAM R67921; Mundiwindi (23°52'S, 120°0'E); WAM R128358; Mt Meharry (23°11°05'S, 118°4730'E); WAM R67921; Mundidindi (23°52'S, 120°10'E); WAM R12280.

*Possible hybrids: Acanthophis wellsi X A. pyrrhus*

7 km NW of Cane River Homestead (22°02'S, 115°35'E); WAM R80430; 7 km NW of Cane River
K.P. Aplin, S.C. Donnellan

Homestead (22°03'S, 115°34'E): WAM R80431; 6 km W of Cane River Homestead (22°05'S, 115°34'E): WAM R80437; 8 km SW of Cane River Homestead (22°08'S, 115°33'E): WAM R80432 and R80442 (7 km); 21 km SW of Cane River Homestead (22°15'S, 115°31'E): WAM R80443; 15 km N of Nanutarra Roadhouse (22°25'S, 115°31'E): WAM R80433; 3 km E of Giralia (22°41'S, 114°25'E): WAM R61357; 16 km NNW Mia Mia Homestead (23°15'S, 114°23'E): WAM R71228.

Material examined electrophoretically

*Acanthophis vellsi*

- Population WE1 (Pannawonica, Western Australia): WAM R113114, R113166, R113167, R113374, R113377, R113378.
- Population WE2 (Cleaverville, Western Australia): WAM R114270.

*Acanthophis pyrrhus*

- Population PY1 (Yuendumu, Northern Territory): EBU E25.

*Acanthophis praelongus*

- Population PR1 (near Heathlands, Queensland): QM J54143.

*Acanthophis antarcticus*

- Population AN1 (Karragullen, Western Australia): WAM R113180.
- Population AN2 (Coffin Bay, South Australia): SAMA R24412, R28460.
- Population AN3 (Reevesby Island, South Australia): SAMA R27242, R28364.
- Population AN4 (Ardrossan, South Australia): SAMA R24221.

*Echiopsis curta*

- Population E1 (Lort River, Western Australia): SAMA R22971.
- Population E2 (Hambridge Conservation Park, South Australia): SAMA R27494.

*Notechis ater*

- Population N1 (Little Dip Conservation Park, South Australia): SAMA R24776.

*Notechis scutatus*

- Population N2 (Coomalbidgup, Western Australia): SAMA R22370.

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Copidognathus (Halacaridae: Acari) from Western Australia: five species of the oculatus group

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Abstract – Five Copidognathus species, taken on the shores of Rottnest Island, Western Australia, are described. The five species, C. culatus sp. nov., C. facetus sp. nov., C. levigatus sp. nov., C. pumicatus sp. nov., and C. rasilis sp. nov., can be attributed to the Copidognathus oculatus group. The oculatus group and the 28 species attributed to this group are diagnosed, the geographical distribution summarized in a map. The southern hemisphere proved to be more rich in species than the northern.

INTRODUCTION

The genus Copidognathus is cosmopolitan, found in marine, diluted brackish and even freshwater; in polar, temperate and tropical waters, from tidal areas down to deep sea basins. Copidognathus inhabits a variety of substrata, its members are found on and in sandy deposits, amongst colonial organisms, algae and vascular plants. Some few species are parasitic (Newell, 1956; Bartsch, 1976). Species belonging to Copidognathus are within a size range of 180-600 μm. The genus includes almost 300 species. Several natural groups have been recognized and diagnosed, examples are the bairdi group (Bartsch, 1984b, 1996, 1997b), carassaviensis group (Bartsch, 1996), gibbus group (Newell, 1971; Bartsch, 1977, 1994, 1997a), pulcher group (Bartsch, 1984a, 1992; Newell, 1984), tricorneatus group (Bartsch, 1997c), and the oculatus group (Bartsch, 1977).

MATERIAL AND METHODS

Halacarid mites were collected by the author in January 1991 on Rottnest Island, Western Australia, while participating in the Fifth International Marine Biological Workshop. The halacarids were cleared in lactic acid and mounted in glycerine jelly. Drawings were prepared using a camera lucida. Holotypes are deposited in the Western Australian Museum (WAM), paratypes in the WAM, the Zoological Institute and Museum, Hamburg (ZMH), and/or the author’s halacarid collection (IB).

Abbreviations used in the descriptions: AD, anterior dorsal plate; AE, anterior epimeral plate; ds, dorsal setae on idiosoma, ds-1 to ds-6, first to sixth pair of dorsal setae; GA, genitoanal plate; GO, genital opening; mxs, maxillary setae; OC, ocular plate(s); P, palp, P-1 - P-4, first to fourth palpal segment; pas, parambularcal setae; PD, posterior dorsal plate; PE, posterior epimeral plate; pgs, perigenital setae; pgs-1 and pgs-2, anteriormost and succeeding pair of pgs; sgs, subgenital setae; vs-3 pair of posteriormost ventral setae on AE. Legs numbered I to IV, leg segments 1 to 6, tarsus on leg I.

SYSTEMATICS

Copidognathus oculatus group

Diagnosis

Dorsal and ventral plates large, areas with membranous integument narrow. Posterior margin of AD and anterior margin of PD truncate. Anterior margin of AD often tricuspid. Posteromedian raised areola on AD either oblong transverse or bow-shaped, sometimes lacking. Gland pores near lateral margins slightly posterior to level of insertion of legs I. CXI elongate, posteriorly generally tail-like, extending beyond level of insertion of leg III. Pair of costae of PD slightly or not raised. PE extending far beyond insertion of leg IV. First pair of gland pores in lateral margins of AD, generally on level with insertion of leg I. Gland pores on PD inconspicuous. Setae ds-1 on AD between gland pores, within anterior margin of posteromedian areola; ds-2 in anteromedial edge of OC; ds-3 to ds-5 on PD. Opposing margins of AE and GA wide, almost truncate. AE with three pairs of ventral setae. PE with one dorsal and three ventral setae. Female genital sclerites with one pair of sgs. Male GA generally with postgenital papilla; perigenital setae arranged in a ring closely around GO. Male genital scleritis in general with one anterior pair and two posterior pairs of subgenital setae. Gnathosoma with one pair of maxillary setae on its base and one on rostrum; tip of rostrum with two pairs of rostral
setae. Tectum often with triangular process. P-2 with one dorsal seta; no seta on P-3; P-4 with three setae basally, one setula and two spurs apically. Legs shorter than idiosoma. Trochanters III and IV lack a distal spiniform process. Telofemur I 1.4–2.4 times longer than high, often with pair of very narrow ventral carinae. Telofemora highest in basal half. Telofemora and tibiae with small medial and lateral articular membranes. General number of setae (exceptions do exist!), from trochanter to tarsus (solenidium and parambulacrall setae excluded): leg I, 1, 2, 5, 4, 7, 6; leg II, 1, 2, 5, 4, 7, 3; leg III, 1, 2, 2, 3, 5, 4; leg IV, 0, 2, 2, 3, 5, 3. Telofemora III and IV lack ventral setae. Tibiae I and II each with three ventral setae, i.e., generally two bipectinate ventromedial setae and one smooth, slender ventral seta. Tibiae III and IV each with two ventral setae; in the majority of species with one bipectinate ventromedial and one smooth ventral seta. Solenidia on tarsi I and II setiform and dorsolateral in position. Tarsi I, III and IV with pair of fossary setae inserted within fossa area. Fossa membranes of tarsi III and IV small or inconspicuous. Pair of claws at end of tarsi each with accessory process and pecten. Claws and pectines on tarsi I and II rather similar in length. Median sclerite with claw-shaped process.

Copidognathus culoatus sp. nov.
Figures 1–14

Material Examined

Holotype

♂, Bickley Bay, Rottnest Island, Western Australia, Australia; 1.5 m depth; seagrass Amphibolis sp. covered with epiphytes and epizoans; 17 January 1991 (WAM 99/103).

Figures 1–7 Copidognathus culoatus sp. nov., ♂: 1, idiosoma, dorsal; 2, idiosoma, ventral; 3, anterior portion of PD; 4, part of AE with epimeral pore; 5, gnathosoma, ventral; 6, gnathosoma, lateral; 7, telofemur to tibia I, lateral aspect and optical section. (cm, cameralosomal membrane; ds-3, third dorsal seta; ep, epimeral pore; epp, epimeral process; l, articular membrane; vs-1, anteriormost ventral seta on AE) Scale line = 50 μm.
Paratypes

Australia: Western Australia: 1 ♂, collection data same as for holotype (ZMH); 1 ♂, collection data same as for holotype (IB).

Other material examined

Australia: Western Australia: 1 ? , Bickley Point; 0.5 m depth; *Amphibolis* sp. covered with epiphytes and epizoans, 18 January 1991 (WAM 99/104).

Description

**Male**

Idiosoma 235–261 μm long, holotype 235 μm long. Dorsal plates with delimited porose areolae, remainder of plates foveate. Rosette pores within porose areolae pycnic, with ostium, 1–2 μm wide, a similar wide alveolus, and almost reduced canaliculi. AD of holotype 60 μm long; with arched anteromedian margin and pair of small lateral protuberances where AD and dorsal portion of AE meet (Figure 1). Transverse porose areola 10 μm long, 40 μm wide. Pair of gland pores in lateral margins, level with anterior margin of transverse areola. OC 95 μm long, 32 μm wide; posterior cornea lightly constricted. Gland pore lateral to posterior cornea; pore canaliculus level posterior margin of that cornea. Tail-like posterior portion of OC rather wide, extending far beyond level of ds-4. Porose areola medial to cornea 12 μm in diameter. PD 158 μm long. Pair of long porose costae mainly two pores or 8–10 μm wide (Figure 3), rarely one

Figures 8–14 *Copidognathus culoatus* sp. nov.: 8, leg I, medial, ♂; 9, leg II, ventromedial, ♂; 10, leg III, medial, ♂; 11, leg IV, medial, ♂; 12, tarsus I, lateral (medial setae and claw omitted), ♂; 13, tarsus II, lateral (medial setae and claw in broken line), ♂; 14, genitoanal plate, ? . Scale line = 50 μm.
pore wide; costae extending anteriad to level of ds-3. Costae in posterior PD convergent but not meeting in the median. Foveae between and lateral to costae 5 µm wide. Pair of small lateral costae in posterior portion of PD. Dorsal setae small; ds-3 to ds-5 inserted lateral to medial costae.

Ventral portions of plates superficially almost evenly punctate; when focussing on deeper layers a faint reticulum present. Marginal portions of plates foveate (Figure 2). AE 92 µm long (with transverse camerostomal membrane included). Epimeral pores constricted by two tines (Figure 4). Epimeral processes I at ventral aspect conical; epimeral processes II lamellar. GA 120 µm long; GO 32 µm long. Distance from GO to GA 1.8 times length of GO. Spermatopositor by 0.3 times length of GO extending anteriorly and distally (Figure 14). Gnathosoma and legs as in male.

Remarks
Copidognathus culoatus is characterized by its transverse, rectangular areola on the AD; the two (to one) pores wide costae on the PD bearing small ostia and very reduced canaliculi; the scaliform postgenital papilla; and the short telofemora.

C. culoatus resembles C. oculatus and C. modestus. In contrast to C. oculatus, C. culoatus has smaller porose areolae on AD and PD, the canaliculi of the rosette pores are almost reduced, and the ovipositor is shorter.

The costae on the PD of C. modestus are as wide as in C. culoatus; in contrast to the latter species, the ventromedial seta on tibia IV is blunt, the female ovipositor extends almost to the pgs-1, and the males have 25–29 pgs.

Etymology
The name 'culoatus' is an anagram of 'oculatus'.

Copidognathus facetus sp. nov.

Material Examined

Holotype
6, Duck Rock, Rottnest Island, Western Australia, Australia; 7–10 m depth; algal hapteres with epifauna; 9 January 1991 (WAM 99/105).

Paratype
Australia: Western Australia: 1♂, collection data same as for holotype (IB).

Description

Male
Idiosoma 190–200 µm long, holotype 200 µm long. Dorsal plates foveate and reticulate; rosette pores lacking. AD 57 µm long; anterior margin with small, rounded median process (Figure 15). Raised areola similar to an inverted Y and ornamented with large foveae; remainder of plate minutely reticulate (Figure 17). OC 75 µm long, 26 µm wide; tail-like posterior portion extending just beyond level of ds-4. OC with two large corneae. PD 137 µm long. Pair of costae delimited, 5 µm wide, ornamented with small, faint foveae (Figure 18). Median and lateral portions of plate minutely reticulated; meshes of reticulum along anterior margin and in posterior portion of PD larger than in remainder of plate. Setae ds-3 to ds-5 long, inserted lateral to costae. Setae ds-6 small.

Major portions of ventral plates evenly punctate; small marginal areas foveate. AE 77 µm long (camerostomal membrane excluded). Epimeral
Copidognathus (Acari) from Western Australia

Figures 15-22 *Copidognathus facetus* sp. nov., ♂: 15, idiosoma, dorsal; 16, idiosoma, ventral; 17, anterior dorsal plate; 18, anterior portion of PD; 19, part of AE with epimeral pore; 20, genitoanal plate; 21, gnathosoma, venter lateral; 22, gnathosoma, lateral. Scale line = 50 μm.

processes lamelliform, very conspicuous (Figure 16). Epimeral pores small, ovate, not constricted by protruding teeth (Figure 19). GA 98 μm long. Distance from anterior margin of GA to GO twice length of GO, distance from posterior margin of CO to end of anal cone same as length of GO. Spermatopositor large (Figure 20); extending far beyond GO.

Gnathosoma 60 μm long, rostrum 27 μm long. Dorsal flank of gnathosomal base coarsely foveate; ventral flank porose. Tectum triangular. Basal pair of maxillary setae moved to basal portion of gnathosomal base (Figure 21). Rostral sulcus extending beyond apical pair of maxillary setae. P-4 almost as long as diagonal length of P-2 (Figure 22).

Legs I and IV almost equal in length; leg II smaller than leg I. Telofemora short, approximately 1.6 times longer than high (Figures 23-26); integument pitted. Legs I and II with telofemora about as long as tibiae; tibiae of legs III and IV longer than telofemora. On tibia II basalmost bipectinate seta almost level smooth ventral seta. Ventromedial seta on tibia III blunt and delicately pectinate; that seta on tibia IV tapering, very delicately serrate. Tarsus I with pair of fossary setae on large fossa membranes; solenidion 9 μm long; famulus lamelliform (Figure 27). On tarsus II fossary setae adjacent and near basis of fossa membranes (Figure 28); solenidion 10 μm long, on lateral fossa membrane. Tarsi III and IV with narrow fossa membranes. Distance between two basal setae on tarsus III same as height of that segment. Tarsus I with pair of doubled pas, tarsus II with singlets.

Claws on leg I not markedly smaller than claws of succeeding tarsi. Each claw with accessory process and pecten. Median sclerite with minute claw-like process.

**Female**

Not seen.
I. Bartsch

Figures 23-28 *Cophidognathus facetus* sp. nov., δ: 23, leg I, medial; 24, leg II, ventromedial; 25, basifemur – tarsus III, medial; 26, leg IV, medial; 27, tarsus I, lateral (medial setae in broken line; medial parambulacral setae and claw omitted); 28, tarsus II, lateral (medial setae in broken line). (fa, famulus; so, solenidion) Scale line = 50 μm.

Remarks

The most conspicuous characters of *Cophidognathus facetus* are the small size (200 μm) and the ornamentation of the AD and PD (raised areola on AD with large foveae; delimited costae on PD with faint, small foveae; remainder of plate minutely reticulated). Rosette pores are lacking.

The Antarctic *Cophidognathus confusus*, the Chilean *C. foivolatus*, and the Caribbean *C. manubriatus*, too, lack rosette pores. The idiosoma of *C. confusus* is very slender, distinctly more slender than in *C. facetus*. In contrast to *C. facetus*, the male GO of *C. foivolatus* is larger relative to length of GA, the distance from GO to the anterior margin of the GA equals 1.7 times the length of GO, and the basal pair of maxillary setae is in normal position (in *C. facetus* the interval between GO and GA is twice the length of the GO, and the basal pair of the maxillary setae is in a more basal position). The sculpturing of the AD and PD of *C. manubriatus* differs from that of *C. facetus*; namely in *C. manubriatus* the median areola on the AD is small and has indistinct pores, the remainder of the plate is covered with large foveae, whereas in *C. facetus* the median areola is large, bow-like, it bears large foveae, the areas outside the median areola are minutely reticulated. *Cophidognathus krantzi*, from Nicobar Islands, Bay of Bengal, is similar in size, the raised areola on the AD resembles that of *C. modestus*. Distinguishing characters are the costae of the PD (in *C. krantzi* with distinct pores, in *C. facetus* with minute foveae) and the insertion of the basal pair of maxillary setae.

Etymology

From 'facetus' L. for gracile, referring to the gracile habitus.
Copidognathus (Acari) from Western Australia

Copidognathus levigatus sp. nov.

Figures 29-43

Material Examined

Holotype

♂, Little Armstrong Bay, Rottnest Island, Western Australia, Australia; 0.5 m deep; heavily encrusted seagrass Posidonia sp.; 16 January 1991 (WAM 99/106).

Paratypes

Australia: Western Australia: 1 ♂, collection data same as above (WAM 99/107); 1 ♂, collection data as above (ZMH); 1 ♂, collection data as above (IB).

Description

Male

Idiosoma 323 µm long, 192 µm wide. Major parts of dorsal plates covered with small rosette pores, irregular in size and shape; remainder of plates foveate. AD 80 µm long, 92 µm wide; anteromedian margin truncate (Figure 29). Integument of anterior two-third slightly raised and with rosette pores; pores 2–5 µm in diameter, with three to ten canaliculi each. Porose areola ending at transverse row of muscle scars (internal apodemes). Area posterior to series of scars approximately 27 µm long, integument covered with small foveae, each 2 µm in diameter. OC 112 µm long, 42 µm wide; extending backward beyond insertion of leg III and to level of ds-4. Anterior cornea circular, posterior cornea oblong, somewhat constricted. Area medial to corneae and along lateral margin of OC with rosette pores, remainder of plate foveate. PD 237 µm long, 148 µm wide. Pair of wide longitudinal 'costae' not raised; with rosette pores; anterior portion of 'costae' approximately five rosette pores wide; middle and posterior portion 10–13 rosette pores wide, or almost 50 µm wide. Median portion of PD oblong, 30 µm wide, with foveate ornamentation. Anterior portion of PD with transverse row of pycnic rosette pores at level of ds-3 (Figure 31). In posterior portion of PD areas with rosette pores meeting medially. Dorsal setae small; ds-1 within areola with rosette pores of AD; ds-4 and ds-5 within 'costae' of PD.

Marginal areas of ventral plates with rosette pores (Figure 30), large ventral portions uniformly porose. Posterior portion of GA covered with minute epicuticular droplets (Figure 32). Ventral setae

![Figures 29-35](Copidognathus levigatus sp. nov., ♂: 29, idiosoma, dorsal; 30, idiosoma, ventral; 31, anterior portion of PD; 32, posterior portion of genitoanal plate; 33, part of AE with epimeral pore; 34, part of tibia and tarsus II, lateral; 35, tarsus I, lateral (medial setae and claw omitted). Scale line = 50 µm.)
slender and short. AE, with narrow camerostomal membrane included, 113 µm long, 165 µm wide. Epimeral processes I moderate in size, at ventral aspect 8 µm long and 9 µm wide; processes II 6 µm long and 10 µm wide. Epimeral pore with medial tooth (Figure 33). GA 179 µm long, 132 µm wide. GO 43 µm long, 34 µm wide; distance from anterior margin of GA to that of GO equalling 2.2 times length of GO. Spermatopositor short, 77 µm long, 62 µm wide; extending beyond GO by length of GO, and reaching to middle of interval between anterior margin of GO and GA. Postgenital papilla small. GO surrounded by 28 sgs. One genital sclerite with three the other with four sgs.

Shape of gnathosoma resembling that of female. Rostrum about as long as gnathosomal base and almost reaching to end of P-2. P-4 somewhat shorter than P-2.

Legs short. Surface of telofemora minutely pitted; ornamentation of tibiae less intense. Trochanters I and II short. Dorsal and ventral setae short. Telofemur I 1.6 times longer than wide. Telofemur I of holotype unilaterally with six setae, four dorsal and two ventral setae. On each tibiae I and II basalmost ventromedial seta tapering, setiform and only very delicately serrate; apicalmost ventromedial seta wider, blunt and faintly bipectinate (Figure 34). Tibiae III and IV each with one wide ventromedial and one slender, smooth ventral seta. Solenidion on both tarsus I (Figure 35) and II 8 µm long. On tarsus II, as on tarsus I, lateral fossary seta on fossa membrane, adjacent to dorsolateral solenidion; medial fossary seta on medial fossa membrane (Figure 34). Tarsus I with pair of doubled pas, tarsus II with pair of singlets; tarsus III with setiform medial and very minute lateral pas; both pas on tarsi IV very small. Interval between two basal setae on tarsus III equalling height of this segment. Tarsi III and IV with fossa membrane.
Claws on tarsus I slightly shorter than on succeeding tarsi. Each claw with accessory process. Pectines on claws III and IV conspicuously long, as in female (Figure 43).

**Female**

Idiosoma 340 μm long, 180 μm wide. Dorsal aspect resembling that of males. GA 177 μm long, 125 μm wide. GO 52 μm long, 28 μm wide. Genital sclerites with pair of short pgs. Interval between anterior margin of GA and GO twice length of GO. Ovipositor by less than half length of GO extending beyond GO, not reaching level of pgs-1 (Figure 36).

Gnathosoma 72 μm long, 56 μm wide, 1.3 times longer than wide. Rostrum 37 μm long, Ventral flank of gnathosomal base punctate, dorsal flank foveate, marginally reticulate; median process of tectum short (Figure 37). Rostral sulcus extending beyond apical pair of maxillary setae (Figure 38).

Leg I wider than leg II. Telofemora I and II 1.5–1.6 times longer than high (Figures 39 and 40); length:height ratio of telofemora III and IV 1.7 (Figures 41 and 42). Tibiae I and II slightly shorter than these legs’ telofemora; tibiae III and IV longer than telofemora III and IV, respectively. Tarsi III and IV as long as tibiae.

**Remarks**

The most marked characters of *Copidognathus levigatus* are the large areolae with irregularly shaped rosette pores on AD and PD, the short telofemora I, and the long pectines on tarsi III and IV. The PD of *C. floridus* also has conspicuously wide porose costae, and the shape of leg I resembles that of *C. levigatus*. In contrast to *C. floridus*, the anterior margin of the AD of *C. levigatus* is truncate and the posterior margin of the porose areola almost transverse.

In contrast to the majority of species of the *oculatus* group, tarsus II of *Copidognathus levigatus* bears the dorsolateral fossary seta adjacent to the solenidion, on the fossa membrane.

**Etymology**

From ‘levigatus’ L., made smooth, referring to the dorsal plates which lack markedly delimited or raised areolae.

*Copidognathus pumicatus* sp. nov. (Figures 44–58)

**Material Examined**

**Holotype**

♂, Bickley Bay, Rottnest Island, Western Australia, Australia; 1.5 m depth; seagrass *Amphibolis* with epiflora and epifauna; 17 January 1991 (WAM 99/108).

**Paratype**

Australia: Western Australia: 1 ♀, data same as for holotype (ZMH).

**Description**

**Male**

Idiosoma 282 μm long, 186 μm wide. AD and PD rather uniformly covered with foveae, 2–4 μm wide; foveae within delicately raised areas somewhat smaller than foveae in remainder of plate. AD 75 μm long, 95 μm wide; anterior margin lightly arched (Figure 44). Bow-shaped raised areola extending almost to lateral margin of plate; approximately 10 of the small foveae in this area surrounded by four to five canaliculi. OC 117 μm long, 36 μm wide; extending posteriad distinctly beyond level of ds-4. Raised area lateral to two corneae with tiny foveae; foveae in remainder of OC 3–4 μm in diameter. PD 202 μm long, 120 μm wide; its ‘costae’ delicately raised, 20 μm wide; integument of ‘costae’ with scattered foveae surrounded by six to seven canaliculi; median portion of PD with larger foveae but no canaliculi (Figure 46). Setae ds-1 to ds-6 small; ds-4 and ds-5 well removed from lateral margins.

Ventral plates uniformly and coarsely porose; no reticulation recognizable. AE 97 μm long, 155 μm wide; epimeral processes small, first pair of processes rounded (Figure 45). Ovate stoma of epimeral pores not constricted by tines (Figure 47). Setae vs-3 close to posterior margin of AE. GA 152 μm long, 112 μm wide. GO 47 μm long, 35 μm wide, in posterior portion of GA. Portions lateral to GO with foveae; several of these foveae with canaliculi in deeper integumental layers. Distance from GO to anterior margin of GA equaling 1.9 times length of GO. Spermatopositor 95 μm long, 62 μm wide; by more than length of GO extending beyond GO, and reaching beyond middle of distance GO to GA. Genital sclerites with three pairs of sgs; beneath anterior portion of genital sclerites pair of ovate areas. Postgenital papilla transverse, narrow. GO surrounded by 23 pgs; posteriormost pair of pgs within basis of postgenital papilla.

Gnathosoma 86 μm long, 55 μm wide, 1.6 times longer than wide. Rostrum 42 μm long, 24 μm wide, slightly shorter than gnathosomal base. Gnathosomal base and basal portion of rostrum with minute foveae. Rostrum not quite extending to end of P-2 (Figure 49). P-4 slightly shorter than P-2. Median process of tectum rounded (Figure 48).

Legs I and IV (with claws included) subequal in length, 0.7 of idiosomal length. Surface of leg segments pitted. Membranes of claw fossa on tarsi II to IV delicately foveate. Telofemora I to IV 1.7 times longer than high (Figures 50–53). Tibiae of legs II, III and IV almost as long as the legs’ telofemora. Tarsi III and IV somewhat longer than tibiae. Ventral setae on legs short. Tibia I ventrally...
with two wide, pectinate setae and one slender, smooth seta. Tibia II ventrally with two setae, namely one bipectinate ventromedial seta and one smooth and slender ventrolateral seta; both setae approximately 17 µm long; dorsally with four setae. Tibiae III and IV each with one bipectinate and one slender, smooth seta. Solenidion on tarsus I 12 µm (Figure 54), on tarsus II 13 µm long. Two distal
Copidognathus (Acari) from Western Australia

Figures 55-58 Copidognathus pumicatus sp. nov.: 55, tip of tarsus II, ventral, \( \delta \); 56, tip of tarsus IV, ventral, m (dorsolateral seta omitted); 57, tarsus II, lateral (medial setae and claw in broken line), \( \delta \); 58, genitoanal plate, \( \varphi \). (ac, accessory process)

fossary setae on tarsus II adjacent near basis of medial fossa membrane (Figure 57). These two distal fossary setae on tarsi I, III and IV on fossa membranes. Distance between two basal setae on tarsus III almost equalling height of tarsus. Tarsus I with pair of doubled pas, tarsi II to IV with pair of singlets.

Claws on tarsi II to IV distinctly longer than those of tarsi I. Claws markedly slender; accessory process on claw I distinct; processes on claws II to IV tiny and moved to end of claws (Figures 55-57). Pecten extending almost from tip to basis of claw.

Female

Idiosoma 263 \( \mu \)m long. Outline of dorsal plates as in male. Ventral plates coarsely porose. GA 133 \( \mu \)m long, 100 \( \mu \)m wide. GO 55 \( \mu \)m long, 27 \( \mu \)m wide; minute foveae ornamenting surface of genital sclerites. Ovipositor large, by 0.6 times length of GO extending beyond anterior margin of GO, and reaching beyond anteriormost pair of pgs (Figure 58). Gnathosoma and legs as in male. Tibiae II as in male with one slender ventrolateral seta and single bipectinate ventromedial seta.

Remarks

The most conspicuous character in both the holotype and paratype of Copidognathus pumicatus is the absence of the second bipectinate seta on tibia II. The chaetotaxy resembles that of protonymphal stages of the genus Copidognathus. Other characters are: porose areolae on dorsal plates hardly delimited from remainder and bearing scattered and pycnic rosette pores, and the claws on tarsi II to IV being slender, with their accessory process moved to the tip of the claws and hence the pecten extending almost to this tip.

In Copidognathus, the number of setae on the tibiae is a generic character; tibiae I and II of adults have three ventral setae each, tibiae III and IV two setae each. In contrast, tibia II in the holotype and paratype of C. pumicatus has two ventral setae. All the other characters of this species distinctly support the congenerity with Copidognathus and also the close relationship to the oculatus group.

Both the outline and the ornamentation of the dorsal plates resembles that of C. levigatus, but in C. pumicatus the areolae with the rosette pores are smaller, the vs-3 are closer to the posterior margin of the AE, the female ovipositor surpasses the anterior pgs; the male spermatopositor is much longer than in C. levigatus; and the pecten on each of the claws of tarsi III and IV extends almost to the tip of the claws.

The shape of the claws on tarsi II to IV, with the pectines extending to the tip, separates C. pumicatus also from all other species of the oculatus group.

Etymology

From 'pumico' L. for polish, referring to the posterodorsal plate that lacks distinctly delimited and raised costae.

Copidognathus rasilis sp. nov.

Figures 59-69

Material Examined

Holotype

\( \varphi \), Nancy Cove, Rottnest Island, Western Australia, Australia; 0.1-0.5 m depth; encrustings on concrete pilings; 12 January 1991 (WAM 99/109).

Paratype

Australia: Western Australia: 1 \( \delta \), collecting as data as above (ZMH).

Description

Male

Idiosoma 174 \( \mu \)m long. Dorsal aspect similar to that of female. AD as in female 48 \( \mu \)m long, 42 \( \mu \)m wide; anterior margin of AD trilobed; anteromedian portion coarsely foveate, foveae 2–5 \( \mu \)m wide;
lateral portions foveate-reticulate (Figure 59). PD 122 μm long, 67 μm wide; pair of 'costae' very faintly delimited from delicately and minutely reticulate remainder of plate. Setae ds-3, ds-4 and ds-5 lateral to 'costae'.

Ornamentation of ventral plates as in female. GA 87 μm long, 65 μm wide; plate uniformly punctate; portions lateral to GO not foveate. GO 26 μm long, 22 μm wide. Distance from anterior margin of GA to GO equalling 1.6 times length of GO; distance from GO to end of GA slightly less than length of GO. Spermatopositor 47 μm long, 38 μm wide; by more than length of GO extending beyond GO. GO surrounded by 21 pgs (Figure 60). Genital sclerites
with three and four sgs. Postgenital papilla lacking.

Gnathosoma 60 μm long. Tectum with small median process. Rostrum not extending beyond P-2; rostrum shorter than gnathosomal base. P-4 slightly longer than P-2 (dorsal length) (Figure 61).

Legs I and IV similar in length. With claws included, length of these legs equalling 0.6 of idiosomal length. Telofemora I to IV with 5, 4, 2, 2 setae.

Female

Idiosoma 187 μm long, 98 μm wide. Anteromedian portion of AD conspicuously foveate, OC and PD very faintly and delicately reticulated. AD 48 μm long, 42 μm wide. Setae ds-1 within posterior margin of foveate areola. Transverse series of internal apodemes near posterior margin. OC 82 μm long, 20 μm wide; the posterior tail-like portion extending far beyond posterior margin. OC and PD very faintly and delicately reticulated. AD 48 pm long, 42 pm wide. Setae ds-1 near lateral margin of PD. Portion which bear small, very faint reticulation. PD 137 pm long, 65 pm wide. Pair of longitudinal setae and margin of AE equalling 20 pm. PE elongate, area anterior and posterior to insertion of leg III similar in length. GA 90 μm long, 58 μm wide; GO 32 μm long, 24 μm wide. Distance from anterior margin of GO to GA equalling 1.3 times length of GO. Ovipositor short, by 7 μm extending beyond GO, far from reaching level of pgs-1.


Leg I larger than leg II; telofemora I and II 1.6–1.7 times longer than high (Figures 66 and 67). Tibiae I and II as long as telofemur II; the basalmost dorsal seta is lacking in both the holotype ♂ and the paratype ♀. In the male, the postgenital papilla is reduced which is likely to be correlated with the general reduction of integumental structures of this small-sized species.

Etymology

From 'rasilis' L. for polished. In this species the posterodorsal plate is almost smooth, a distinct ornamentation such as delimited costae or large foveae is lacking.

GENERAL REMARKS AND NOTES ON BIOGEOGRAPHY

The Copidognathus oculatus group was diagnosed by Bartsch (1977), and seven species were attributed to the group. Newell’s key group 5200 (Newell, 1984) to its major part is identical with the oculatus group; Newell (1984: 140) placed 13 species, mainly from the southern polar and cold-temperate zone, into that key group, viz. C. anops, C. arcuatus, C. aricae, C. arnaudi, C. confusus, C. cornutus, C. floridus, C. foveolatus, C. hureai, C. marcanetri, C. porosus, C. vandoffeni, C. ypsilophorus. Another five species (C. aequilavistitus, C. crypticus, C. conmatops, C. granosus, C. sigillatus), closely related to C. oculatus, are in key group 7700 (Newell, 1984: 181). In the same year, Bartsch (1984c) added the Caribbean species C. manubriatus and C. modestus to the oculatus group.

At present, the oculatus group comprises 28 species, doubtful species included. The following annotated list is mainly compiled according to the descriptions of the species and not based on personal microscopic studies; misinterpretations may have occurred. The species C. aricae and C. arcuatus, by Newell (1984) attributed to the key group 5200, are not included in the list of species; both obviously are not closely related to C. oculatus.

As shown in the map (Figure 70), the oculatus group is present world-wide, in polar, temperate as well as in tropical areas. Representatives of the group have been taken in the littoral, sublittoral and bathyal zone. Noteworthy is the diversity of the fauna on the southern hemisphere. In the Antarctic region (the Antarctic continent, the Palmer
Peninsula and the islands south of the convergence zone) six out of the seven *Copidognathus* species proved to belong to the *oculatus* group (Bartsch, 1993); these are *C. arnaudi*, *C. confusus*, *C. floridus*, *C. marcandrei*, *C. porosus*, and *C. vanhoeffeni*. The species *C. aequalivestitus*, *C. commatops*, *C. crypticus*, *C. granosus*, *C. hureaui*, *C. kerguelensis*, *C. marcandrei*, *C. sigillatus*, and *C. ypsilonophorus* are recorded from Subantarctic waters, namely the shores of southern South America, South Georgia, and Kerguelen Islands. Several species both within and between the Antarctic and Subantarctic region are almost identical in general facies, nonetheless, the species of the Antarctic and Subantarctic region are distinct and no species is known to inhabit both areas. On the Northern hemisphere, *C. latisetus* and *C. oculatus* live in the northeastern Atlantic and adjacent seas, and *C. pacificus* in the northwestern Pacific Ocean. No member of the *oculatus* group is recorded from the shores of the cold-temperate northwestern Atlantic ocean. Species from warm-water areas are *C. manubriatus* and *C. modestus*, present in the Caribbean area, and *C. krantzi*, in the Bay of Bengal. An undescribed species from the Philippines is in the author’s halacarid collection. The fauna of Rottnest Island, Western Australia, known to harbour both tropical and temperate elements (Wells and Walker, 1993) proved to contain five species of the *Copidognathus oculatus* group.

Of the five species of the *oculatus* group taken on the shores of Rottnest Island, *C. levigatus* and *C. pumicatus* as well as *C. facetus* and *C. rasilis* demonstrate close similarities in the external characters which clearly separate these couples from other species. The couples *C. levigatus* / *C. pumicatus* and *C. facetus* / *C. rasilis* are supposed to be sister species.

**ANNOTATED LIST OF SPECIES**

The list includes 28 species of the *oculatus* group; reliable descriptions are given in square brackets.

*Copidognathus aequalivestitus* Viets, 1950 [Viets, 1950]

**Diagnosis**

Telofemur I delicately and minutely foveate, 1.6 times longer than high. Tarsus II with two distal fossary setae at basis of claw fossa. Tibiae III and IV each with bipectinate ventromedial seta. Claw pectines with distinct tines.

Remarks
In the type series, housed in the ZMH, the OC end with an elongate tail which extends far beyond the insertion of leg III. *C. aequalivestitus* can be identified with help of the uniformly porose dorsal and ventral plates.

Distribution
Falkland Islands; 16 m depth; gravel, shell and algae (Viets, 1950).


Diagnosis

Remarks
In contrast to the majority of species of the *oculatus* group, the OC of *C. anops* are not caudiformly prolonged. The costae of the PD of *C. corneatus*, *C. marcandrei*, *C. porosus*, and *C. vanhoefeni*, species with rather short OC, are distinct from the narrow, one-pore wide costae of *C. anops*.

Distribution
Off Peru; 1,565 m depth; rocky bottom (Newell, 1971, 1984).

*Copidognathus amaudi* Newell, 1984 [Newell, 1984; Bartsch, 1993]

Diagnosis
Idiosoma 290–360 µm long. Porose areolae with deep pores (ostium and alveolus but no canaliculi); remainder of dorsal plates foveate. Posteromedian areola on AD bow-shaped. Posterior portion of OC caudiform, reaching just beyond level of ds-4. Medial costae on PD five to nine pores wide; lateral costae present. Porose areolae within margins of PE and GA with rosette pores (small surficial ostia; canaliculi in deeper integumental layers); ventral portions of AE, PE and GA with punctate panels. Epimeral processes I distinct but short. Ovipositor extending halfway between pgs-1 and pgs-2. Male GO surrounded by 24 pgs. Spermatopositor extending midway between distance GO – GA. No pgs at basis of postgenital papilla. Gnathosoma 1.6 times longer than wide. Rostrum extending to end of P-2. Tectum with median process. Telofemur I panelled, 1.5 times longer than high. Ventromedial seta on both tibia III and IV bipectinate. Paired fossary setae on tarsus II at basis of claw fossa. Tarsi III and IV with membranes of claw fossa greatly reduced. Claw pectines with long, slender tines.

Remarks
*C. amaudi* resembles *C. aequalivestitus* in general facies but the ornamentation of the dorsal and ventral plates is different.

Distribution
Terre Adélie, South Shetland Islands, Palmer Archipelago; 12–370 m depth; hydrozoans, sponges, holdfasts of brown algae (Newell, 1984; Bartsch, 1993).

*Copidognathus commatops* Newell, 1984 [Newell, 1984]

Diagnosis
Idiosoma 284–314 µm long. Posteromedian areola of AD slightly longer than wide. Long, caudiform posterior portion of OC extending distinctly beyond level of ds-4. PD with pair of costae, each three rosette pores wide. Rosette pores with large ostia and numerous canaliculi. Remainder of plate strongly panelled. Ventral plates uniformly punctate. Epimeral process I low. Ovipositor extending anisodactyl beyond pgs-1; that pair of setae at 0.4 relative to length of GA (from anterior to posterior). Male GO surrounded by approximately 50 pgs (21–30 on each side). Spermatopositor by length of GO extending beyond GO. Postgenital papilla well developed; flanked by isolated pair of pgs. Tectum of gnathosoma gently rounded. Telofemur I minutely and uniformly reticulate, 1.4 times longer than high. Ventromedial seta on both tibia III and IV bipectinate. On tarsus II, two distal fossary setae inserted almost adjacent near basis of claw fossa. Claw pectines well developed.

Remarks
Newell (1984) attributed *C. commatops* both to the key group 5200 and to 7700. Approximately one-third of the species of the *oculatus* group have small or reduced epimeral processes I. *C. commatops* can be separated from the
other species with small epimeral processes on the basis of the shape and ornamentation of the porose areolae.

**Distribution**

Chile, near Punta Arenas; low to midtidal zone; very coarse sand (Newell, 1984).

**Copidognathus confusus** Newell, 1984 [Newell, 1984; Bartsch, 1993]

**Diagnosis**

Idiosoma slender, 355-360 µm long. Dorsal plates lack distinct rosette pores. Median areola on AD foveate. Tail-like posterior portion of OC reaching level of ds-4. PD almost three times longer than wide; panelled; some specimens with single row of weakly developed pores within costae. Epimeral processes extremely minute. Marginal portions of ventral plates foveate, ventral portions delicately pitted. Ovipositor extending beyond GO but far from reaching level of pgs-1. Male GO surrounded by 30 pgs. Spermatopositor reaching halfway between distance from anterior margin of GO to GA. Postgenital papilla moderate in size. Gnathosoma slender. Rostrum extending to end of P-2. Telofemur I reticulate; length twice the height. Fossa membranes of tarsi II, III and IV almost completely reduced. Paired fossary setae on tarsus II dorsal in position, not within area of claw fossa. Claw pectines with small tines.

**Remarks**

*C. confusus* can be identified on the basis of its very slender idiosoma.

**Distribution**

Terre Adelie, Palmer Archipelago (Nowell, 1984; Bartsch, 1993).


**Diagnosis**

Idiosoma 305-331 µm long. Posteromedian areola of AD large, oval, with 25-35 typical rosette pores. Caudiform posterior portion of OC extending to ds-4. PD uniformly covered with prominent, circular panels, some of which show poorly developed rosette pores; no costae present. Ventral plates with widely spaced porose panels. Epimeral processes absent. Ovipositor extending beyond pgs-1. Male with 12-14 pgs on either side of GO. Spermatopositor large, extending far beyond ring with pgs. Postgenital papilla large; with pair of pgs at its basis. Tectum of gnathosoma heavily panelled, median process bluntly rounded. Integument of telofemora delicately reticulate and with canals. Telofemur I 1.3 times longer than high. Ventromedial seta on both tibia III and IV bipectinate. Tarsus II with two distal lossary setae inserted adjacent at basis of claw fossa. Tarsi III and IV with fossa membranes. Claw pectines with tines.

**Remarks**

In contrast to the similar *C. aequalvestitus*, the porose areolae of *C. crypticus* contain typical rosette pores.

**Distribution**

Off Chile; 485 m depth (Newell, 1971, 1984).

**Copidognathus crypticus** Newell, 1984 [Newell, 1984]

**Diagnosis**

Idiosoma 324-355 µm long. Posteromedian areola of AD large, oval, with 25-35 typical rosette pores. Caudiform posterior portion of OC extending to ds-4. PD uniformly covered with prominent, circular panels, some of which show poorly developed rosette pores; no costae present. Ventral plates with widely spaced porose panels. Epimeral processes absent. Ovipositor extending beyond pgs-1. Male with 12-14 pgs on either side of GO. Spermatopositor large, extending far beyond ring with pgs. Postgenital papilla large; with pair of pgs at its basis. Tectum of gnathosoma heavily panelled, median process bluntly rounded. Integument of telofemora delicately reticulate and with canals. Telofemur I 1.3 times longer than high. Ventromedial seta on both tibia III and IV bipectinate. Tarsus II with two distal lossary setae inserted adjacent at basis of claw fossa. Tarsi III and IV with fossa membranes. Claw pectines with tines.

**Remarks**

In contrast to the similar *C. aequalvestitus*, the porose areolae of *C. crypticus* contain typical rosette pores.

**Distribution**

Off Chile; 485 m depth (Newell, 1971, 1984).

**Copidognathusculoatus** sp. nov.

**Diagnosis**

Idiosoma 235-261 µm long. Porose areolae of dorsal plates with pycnic rosette pores (with ostium and alveolus but almost reduced canaliculi).

Remarks

C. floridus can be separated from congeners on the basis of the collar-like anterior AE.

Distribution

Palmer Archipelago, Terre Adélie; shallow water; amongst sponges and algae (Newell, 1984; Bartsch, 1993).

Copidognathus foveolatus

Newell, 1984 [Newell, 1984]

Diagnosis


Remarks

C. foveolatus has the basal pair of maxillary setae in normal position, whereas in the similar C. facetus these setae insert more basally.

Distribution

Off Chile, islands San Felix and Juan Fernandez; intertidal; on algae (Newell, 1984).

Copidognathus granosus

Newell, 1984 [Newell, 1984]

Diagnosis


Remarks

C. floridus can be separated from congeners on the basis of the collar-like anterior AE.

Distribution

Palmer Archipelago, Terre Adélie; shallow water; amongst sponges and algae (Newell, 1984; Bartsch, 1993).
transverse, oval. Posterior caudiform portion of ocular plate extending far beyond ds-4. Costae on PD distinct only in posterior portion of plate, here two to three rosette pores wide. AE and PE with marginal areolae. Epimeral process I low, shelf-like. Male GO surrounded by about 28–30 pgs. Spermatopositor by more than length of GO extending beyond GO. Pair of pgs at basis of well developed postgenital papilla.

Remarks
In contrast to other species of the oculatus group, the costae with rosette pores are present only in the posterior portion of the PD.

Distribution
Chile, near Punta Arenas; low to midtidal zone; very coarse sand (Newell, 1984).

Copidognathus hureaui Newell, 1984 [Newell, 1984]

Diagnosis
Idiosoma 294–344 μm long. Dorsal plates with rosette pores. Posteromedian porose areolae of AD small, transverse elliptical. Posterior portion of OC long, tail-like. Medial costae on PD feebly developed, with scattered, irregularly formed rosette pores and coarse pores. Lateral costae small, slightly raised. Remainder of PD panelled. Epimeral process I small, pointed. Ovipositor not reaching to pgs-1. Spermatopositor extending halfway between anterior margin of GO and GA. GO surrounded by approximately 36 pgs. Postgenital papilla very long, with pair of pgs at its basis. Gnathosoma slender; length more than twice its width. Rostrum extending beyond P-3. Telsonex more than 1.8 times longer than high. Ventromedial seta on both tibia III and IV delicately bipectinate. Tarsus II with two distal fossary setae adjacent at basis of claw fossa. Tarsus IV with four dorsal setae. Tarsi III and IV lack fossary lamellae. Tines of pectines distinct.

Remarks
C. hureaui has a very slender rostrum and, unique within the oculatus group, tarsus IV bears four dorsal setae.

Distribution
Kerguelen; amongst algae from shallow water (Lohmann, 1907; André, 1933; Newell, 1984).

Copidognathus kerguelensis (Lohmann, 1907) [Lohmann, 1907; André, 1933]

Diagnosis
Idiosoma 400 μm long. Anterior portion of PD more narrow and reticulation coarser than in C. oculatus, else similar to C. oculatus. OC long, tail-like. Gnathosoma 1.6 times longer than wide. Rostrum short, far from reaching end of P-2 (Lohmann, 1907: Fig. 12; André, 1933: Figs 7–9).

Remarks
The majority of species of the oculatus group have a slender rostrum that extends almost to the end of P-2, in contrast, the rostrum of C. kerguelensis is very short.

Distribution
Kerguelen; amongst algae from shallow water (Lohmann, 1907; André, 1933; Newell, 1984).

Copidognathus krantzi Chatterjee, 1992 [Chatterjee, 1992]

Diagnosis

Remarks
In contrast to other small-sized members of the oculatus group with similar porose areolae (C. facetus, C. foveolatus, C. manubriatus), the AD, PD and GA of C. krantzi bear rosette pores.

Distribution
Nicobar Islands; amongst bunches of the green algae Halimeda (Chatterjee, 1992).

Copidognathus latisetus Viets, 1940 [Viets, 1940; Bartsch, 1977]

Diagnosis
Idiosoma 248–290 μm long. Porose areolae of dorsal plates with rosette pores, remainder of plate reticulate, each panel subdivided. Posteromedian areola on AD transverse, oval. Posterior caudiform portion of OC reaching distinctly beyond level of ds-4. Costae on PD two rosette pores wide. PE and GA marginally with large porose areolae; ventral portions of plates punctate. Ovipositor not reaching level of pgs-1. Male with 12–15 pgs on each side of GO.
**Copidognathus** (Acari) from Western Australia

Spermatopositor not reaching beyond midline between distance GO – GA. Postgenital papilla large, with one pair of pgs. Gnathosoma 1.6–1.7 times longer than wide. Tectum with median process. Rostrum extending almost to end of P-2. Panels on telofemora minutely reticulated. Telson I 1.7–1.9 times longer than wide. Tarsi III with four dorsal setae; distance between two basalmost setae more than height of the segment. Ventromedial seta on both tibia III and IV blunt and bipectinate. Fossa membranes on tarsi III and IV inconspicuous. Claw pectines with numerous tines.

**Remarks**

*C. latisetus* is separated from the syntopic *C. oculatus* on the basis of its more slender idiosoma, gnathosoma and telofemora.

**Distribution**

Mediterranean, northeastern Atlantic, North Sea; shallow water, from tidal to 42 m depth; sandy deposits, algae, subtidal barnacles (Viets, 1940; Bartsch, 1977, 1980, 1985; Green and MacQuitty, 1987).

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**Copidognathus levigatus** sp. nov.

**Diagnosis**


**Distribution**

Western Australia; 0.5 m depth; heavily encrusted seagrass *Posidonia* sp.

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**Copidognathus manubriatus** Viets, 1936 [Viets, 1936; Bartsch, 1984c]

**Diagnosis**

Idiosoma 180–207 µm long. Major parts of dorsal plates reticulate to foveate; raised areolae very faintly foveate, at low magnification smooth; rosette pores lacking. Raised areola on AD rectangular. OC posteriorly tail-like, extending beyond level with ds-4. PD with pair of costae. Ventral plates uniformly punctate. Epimeral processes I enlarged. Ovipositor short, hardly extending beyond GO. Gnathosoma approximately 1.5 times longer than wide. Rostrum not reaching end of P-2. Tectum triangular. Telofemora 1.5–1.6 longer than high. Tibiae III and IV each with one pectinate ventromedial and one smooth ventral seta. Tarsus II with pair of fossary setae near basis of claw fossa. On tarsus III, interval between two basalmost setae slightly more than height of that segment. Tarsi III and IV with narrow membranes of claw fossa. Claw pectines with delicate tines.

**Remarks**

*C. manubriatus* resembles *C. facetus* and *C. foveolatus* in respect to size of the idiosoma and ornamentation of the plates. The ovipositor of *C. manubriatus* is much shorter than in *C. foveolatus*, and the basal pair of maxillary setae is not in a basal position as in *C. facetus*.

**Distribution**

Caribbean area; shallow water (Viets, 1936; Bartsch, 1984c).

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**Copidognathus marcandrei** Viets, 1950 [Viets, 1950; Newell, 1984; Bartsch, 1993]

**Diagnosis**

Idiosoma 470–500 µm long. Porose areolae of dorsal plates with rosette pores. Posterior median areola on AD bow-shaped. Posterior portion of OC elongate, pointed but not tail-like, not reaching level of ds-4. PD with pair of large medial and small lateral costae; medial costae in anterior half one to two rosette pores wide. Integument outside costae panelled. Marginal and lateral porose areolae of ventral plates with rosette pores; ventral areas punctate. Epimeral processes I moderately developed. Ovipositor almost extending to pgs-1. Male GO surrounded by 46 pgs. No pgs at basis of postgenital papilla. Gnathosoma 1.7 times longer than wide. Rostrum not reaching end of P-2. Length of telofemur I equalling twice its height; integument panelled. Tibiae III and IV ventrally each with one bipectinate and one smooth seta. Distance between two basalmost setae on tarsus III more than height of that segment. Fossa membranes on tarsi II to IV reduced. Claw pectines with large tines.
Remarks

Short OC as in C. marcandrei are also present in C. anops, C. corneatus, C. porosus, and C. vanhoeffi. In C. corneatus and C. vanhoeffi, the costae of the PD have porose swellings, similar swellings are not present in C. marcandrei. C. anops is much smaller than C. marcandrei, and the costae of its PD are one pore wide. In C. porosus the arrangement of the costae, the ovipositor, and the male pgs is different from that of C. marcandrei.

Distribution

South Georgia; 22 m depth; algae (Viets, 1950).

Copidognathus modestus Bartsch, 1984 [Bartsch, 1984c]

Diagnosis

Idiosoma 253–263 µm long. Raised areolae of dorsal plates with rosette pores; remainder of plate foveate. AD with transverse areola. Tail-like posterior portion of OC extending far beyond insertion of leg III. Medial costae of PD one to three rosette-pores wide. Marginal areas of ventral plates with rosette pores, ventral areas punctate. Epimeral process I pointed. Ovipositor almost reaching level of pgs-1. Male GO surrounded by 25–29 pgs. Spermatopositor large. No pgs at basis of postgenital papilla. Rostrum not reaching end of P-2. Telofemur I minutely reticulate, 1.4–1.5 times longer than high. Tibiae III and IV each with one bipectinate and one smooth seta. Tarsi III and IV with narrow fossa membranes. Claw pectines with large tines.

Remarks

C. modestus is most similar to C. culoatus and C. oculatus. Discriminating characters are mentioned after the diagnosis of C. oculatus.

Distribution

Caribbean area; shallow water (Bartsch, 1984c).

Copidognathus oculatus (sensu Lohmann, 1889)

[Lothmann, 1889; Bartsch, 1977]

Diagnosis

Idiosoma 270–322 µm long. Anterior margin of AD with median process. Tail-like posterior portion of OC extending far beyond insertion of leg III. PD with pair of medial and pair of lateral costae. Epimeral processes I well developed. Male GA with approximately 50 (?) pgs. Shape of gnathosoma not known. Telofemora I short, approximately 1.4 times longer than high.

Remarks

According to Makarova (1975), the species resembles C. oculatus. The description is too fragmentary for detailed comparison.

Distribution

Kurilen Islands (Makarova, 1975, 1977).

Copidognathus pacificus Makarova, 1975

[Makarova, 1975]

Diagnosis

Idiosoma 372 µm long. Anterior margin of AD with median process. Tail-like posterior portion of OC extending far beyond insertion of leg III. PD with pair of medial and pair of lateral costae. Epimeral processes I well developed. Male GA with approximately 50 (?) pgs. Shape of gnathosoma not known. Telofemora I short, approximately 1.4 times longer than high.

Remarks

According to Makarova (1975), the species resembles C. oculatus. The description is too fragmentary for detailed comparison.

Distribution

Kurilen Islands (Makarova, 1975, 1977).
dorsal plates with rosette pores. Posteromedian areola on AD bow-shaped. OC posteriorly pointed, elongate but not tail-like, slightly extending beyond insertion of leg III but far from reaching level ds-4. PD with pair of raised medial and lateral costae; medial costae three to five rosette pores wide, towards posterior end six pores wide; lateral costae lack similar rosette pores. Areas between costae panelled, each panel pitted. Large marginal and lateral areolae of AE, PE and GA with rosette pores; remainder of plate punctate, often arranged within polygons. Epimeral processes I small, rounded. Ovipositor reaching halfway between pgs-1 and pgs-2. Male GO surrounded by approximately 50 pgs. Rostrum extending to end of P-2. Telofemora coarsely panelled, each panel pitted. Telofemur I 2.0–2.1 times longer than high; ventral margin delicately serrate. Ventromedial seta of tibia IV bipectinate as that seta of tibia III. Distance between two basal setae on tarsus III more than the height of this segment. Membranes of claw fossa on tarsi III and IV reduced. Tines of claw pectines minute.

Remarks

C. porosus is one of the large-sized species within the oculatus group. It is similar to C. marcanndrei but its OC are shorter, the porose costae on the PD wider, and the ovipositor is shorter than in C. marcanndrei.

Distribution
Palmer Archipelago, Anvers Island; 13 m depth; brachiopods shells, algae, mud (Newell, 1984; Bartsch, 1993).

Copidognathus pumicatus sp. nov.

Diagnosis
Idiosoma 263–285 μm long. AD and PD rather uniformly covered by foveae; raised areas with slightly smaller foveae. Posteromedian areola on AD very wide. Posterior tail-like portion of OC extending beyond ds-4. Costae on PD only delicately raised, scattered foveae surrounded by canaliculi. Ventral plates coarsely porose. Epimeral process I small, rounded. Ovipositor extending anteriorly far beyond pgs-1. Male GA with 23 pgs. Spermatopositor large, extending beyond middle line of claw fossa. Rostrum extending almost to end of P-2. Median process of tectum rounded. Integument of telofemora foveate. Telofemur I 1.7 times longer than high. Distance between two basal setae of tarsus II slightly less than segment’s height. Claws on posterior tarsi slender; accessory processes of claws II to IV tiny and moved to end of claws; pectines long; tines of pectines long.

Distribution
Western Australia; 1.5 m depth; seagrass Amphibolis sp.

Copidognathus rasilis sp. nov.

Diagnosis
Idiosoma 174–187 μm long. Rosette pores lacking. Anterior portion of AD foveate. Posterior tail-like OC extending far beyond level of insertion of leg III and somewhat beyond ds-4. Faintly delimited costae of PD almost plain; remainder of plate minutely reticulate. Ventral plates delicately punctate. Epimeral process I long. Ovipositor short, only slightly extending beyond GO and far from reaching to pgs-1. Male GO surrounded by 21 pgs. Large spermatopositor reaching far beyond middle of interval between GO and GA. Postgenital papilla lacking. Tectum of gnathosoma with small median process. Rostrum extending almost to end of P-2. Telofemur I 1.6–1.7 times longer than high. Ventromedial seta on tibia III and bipectinate, on tibia IV long, slender, tapering. Tarsus II with pair of fossary setae near basis of claw fossa. Distance between two basal setae on tarsus III almost equalling height of that segment. Tarsi III and IV with narrow membranes of claw fossa. Tines of claw pectines small.

Distribution
Western Australia; 0.1–0.5 m depth; encrustings on concrete pilings.

Copidognathus sigillatus Newell, 1984 [Newell, 1984]

Diagnosis

Remarks
C. sigillatus resembles C. aequalivestitus; the most marked difference is the presence of rosette pores in the porose areolae of C. sigillatus vs the uniform punctation without any ostia and alveoli in C. aequalivestitus.
**Copidognathus vanhoeffeni** (Lohmann, 1907)

**Diagnosis**


**Remarks**

The AD of both *C. ypsilophorus* and *C. floridus* has a porose areola resembling an inverted 'Y'. In *C. floridus* the porose areola on the PD are much wider than in *C. ypsilophorus*. The female GA of *C. floridus* is longer relative to the GO and the insertion of pgs-1.

**Distribution**

Wilhelm II Coast, Terre Adélie, Palmer Archipelago; 46-385 m (Lohmann, 1907; Newell, 1984; Bartsch, 1974, 1993).

**ACKNOWLEDGEMENTS**

The halacarid mites described in this paper were collected during an International Marine Biological Workshop on the Island Rottnest in April 1991. Thanks are due to Dr F.E. Wells, organizer of the workshop, his colleagues and the participants of the workshops for the very enjoyable days on Rottnest Island.

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Copidognathus (Acari) from Western Australia


Manuscript received 19 November 1998; accepted 3 March 1999.
Discovery of the spider *Ambicodamus marae* (Araneae: Nicodamidae) in the northern jarrah forest of Western Australia

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Abstract - The discovery of *Ambicodamus marae* Harvey, 1995, in jarrah forest near Jarrahdale, in the Darling Range of Western Australia is reported. This finding represents a northern range extension of over 250 km and reveals that *A. marae* is not limited to the extreme south-west of Western Australia as originally reported by Harvey (1995).

### INTRODUCTION

Members of the family Nicodamidae are brightly coloured small spiders. They possess either a black, brown, purplish or iridescent blue abdomen, which is contrasted with a bright orange-red cephalothorax and bright red or yellow legs tipped with black (Harvey, 1995). They build small, tough sheet webs at ground level against stones, logs, and low vegetation (Clyne, 1969; Main, 1976; Browne, 1979). Nicodamids are found commonly in eucalypt forests of eastern, southern and western Australia (Clyne, 1969; Main, 1976).

In a review of the family, Harvey (1995) found *Ambicodamus marae* to be known only from the extreme south-west of Western Australia. Almost all specimens were collected between Bluff Knoll (Stirling Range National Park) in the east, Beedelup near Pemberton in the west, and directly south of these locations (Figure 1) (Harvey, 1995). Only three specimens had collection localities outside of this area; two from Geraldton and one from Mt Cooke (Figure 1). Harvey (1995) considered the Geraldton specimens to have been incorrectly labelled and their collection localities erroneous. The locality data of the Mt Cooke specimen was thought to be doubtful for two reasons (M.S. Harvey, pers. comm.). Firstly, *A. marae* was known only from the extreme south-west of Western Australia. In particular the limited area of high rainfall (>1000 mm) on which karri forest (*Eucalyptus diversicolor*) predominates (Harvey, 1995). Secondly, despite extensive surveys of the Mt Cooke area during the early 1990's he was unable to relocate *A. marae* (M.S. Harvey, pers. comm.).

### METHODS

Pitfall trapping of spiders was undertaken between 12–19 September 1997, at Alcoa of Australia Ltd.'s Jarrahdale minesite (32°17'S, 116°08'E) (Figure 1). The study site represented an area of unmined Open Forest (Specht, 1970) where mean annual rainfall exceeds 1200 mm. Jarrah (*Eucalyptus marginata*) and marri (*E. calophylla*) were co-dominant trees. An understorey of small trees (3–7 m) was present; mainly *Banksia grandis*, *Persoonia longifolia* and *P. elliptica*. These overtopped other understorey species such as grass-trees (*Xanthorrhoea preissii* and *Kingia australis*), cycads (*Macrozamia riedlei*) and legumes dominated by the genera *Acacia*, *Bossiaea* and *Kennedia*. This site, last burnt nine years previously, had not been heavily disturbed by firewood harvesting or dieback, and is considered to be one of the least disturbed patches of forest surrounding the mine (J. Koch, Alcoa of Australia, pers. comm.).

### RESULTS AND DISCUSSION

Forty-six adult male and two adult female *A. marae* were captured; no juveniles were present. A reference collection of six males and a female has been deposited in the Western Australian Museum (WAM 99/251-257). The collection of *A. marae* from the study site described above reveals that *A. marae* is not limited to the extreme south-west of Western Australia. This finding represents a northern range extension of over 250 km. Furthermore, it suggests that the record of *A. marae* from Mt Cooke is likely to be valid since Mt Cooke is only 30 km south-east of the Jarrahdale minesite. However, Harvey’s inability to relocate *A. marae* at Mt Cooke suggests that this population may be locally extinct (M.S. Harvey, pers. comm.).

Harvey (1995) suggested that *A. marae* occurs in high rainfall areas (>1000 mm) and listed the karri forest as suitable habitat. He also recorded *A. marae* from the Stirling Range outside the distribution of the karri forest (Churchill, 1968).
These specimens, may represent records of *Ambicodamus marae* from jarrah, marri and wandoo (*E. wandoo*) woodlands, or jarrah dominated mallee (Keighery and Beard, 1993). While rainfall at my study site also was >1000 mm, the vegetation community differed (from those listed above) in that it was jarrah forest. Thus, *Ambicodamus marae* must now be considered to inhabit also a small area of high rainfall in the northern jarrah forest. Interestingly, extensive surveys to locate *Ambicodamus marae* in high rainfall areas of karri forest between the western edge of the Darling Range and the west coast have proved unsuccessful (Harvey, pers. comm.). As such, the western boundary of *Ambicodamus marae*‘s distribution is considered to be the western edge of the Darling Range (Harvey, 1995). Hence, it is likely that *Ambicodamus marae*‘s distribution is influenced not only by rainfall but geomorphological factors.

**CONCLUSION**

*Ambicodamus marae* is not limited to the extreme south-west of Western Australia. Its distribution includes a population in northern jarrah forest surrounding the Jarrahdale minesite. As such, other areas of suitable jarrah forest within the Darling Range should be investigated to determine whether the northern and southern populations of *Ambicodamus marae* are isolated from each other.

**ACKNOWLEDGEMENTS**

I thank Mark Harvey for specimen identification, critical comments on the manuscript and figure 1. Helpful comments and suggestions were made by Jonathan Majer and Erich Volschenk, also. This research was funded by Alcoa of Australia Ltd. The following organisations generously provided access to the study site: Alcoa of Australia Ltd.; the Western Australian Department of Conservation and Land Management; and the Western Australian Water Corporation.

**REFERENCES**


Ambicodamus marae in the norther jarrah forest


Manuscript received 11 June 1998; accepted 3 March 1999.
New cockroach species, redescriptions, and records, mostly from Australia, and a description of *Metanocticola christmasensis* gen. nov., sp. nov., from Christmas Island (Blattaria)

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Abstract — *Metanocticola christmasensis* gen. nov., sp. nov. from Christmas Island, is described. The genus differs from *Nocticola* Bolivar in the male having a sex gland on the metanotum, which is unique among cockroaches. *Robslielfordia frascrensis* sp. nov., *Parasigmoidella atypicalis* sp. nov., *Parasigmoidella mayriverana* sp. nov. (Blattellidae), and *Molytria vegranda* sp. nov. (Blaberidae) are described. Several species are redescribed and some new cockroach records, mostly from Australia, are presented.

INTRODUCTION

This paper is the result of a study of specimens sent to me for identification by several museums, as well as some of the material housed in the Museum of Comparative Zoology, Harvard University. Most of the material is from Australia; several Australian genera (e.g., *Ecloneura* Shelford, *Balia* Tepper, *Ellipsidion* Saussure, *Carbrunneria* Princis, etc.) are omitted because I am revising these taxa which have a large number of undescribed species. Also, non-Australian specimens (mostly Indo-Malayan) that were in the collections have been reported elsewhere (Roth, 1999: 109). Roach and Rentz (1998: 21) have given a catalogue of the cockroaches of Australia.

The following museums and individuals loaned me specimens, and the abbreviations are those used in the text to indicate the sources of the specimens examined: ANIC = Australian National Insect Collection, CSIRO, Canberra, ACT, Australia; Dr David Rentz. ANSP = Academy of Natural Sciences of Philadelphia, PA, U.S.A.; Mr Donald Azuma. BPBM = Bernice P. Bishop Museum, Honolulu, Hawaii, U.S.A.; Mr Gordon N. Nishida. DARA = Department of Agriculture, Biological and Chemical Research Institute, Rydalmere, New South Wales, Australia; Dr G. Brown. HECO = Hope Entomological Collections, University Museum, Oxford, England; Dr George C. McGavin and Mr Ivan Lansbury. MCZ = Museum of Comparative Zoology, Harvard University, Cambridge, MA, U.S.A. NHMB = Natural History Museum, Basel, Switzerland; Dr M. Brancucci. NMV = Museum of Victoria, Melbourne, Victoria, Australia; Ms Catriona McPhee. PMYU = Peabody Museum of Natural History, Yale University, New Haven, CT, U.S.A.; Dr Charles Remington. QM = Queensland Museum, Brisbane, Australia; Dr G.B. Monteith. SAM = South Australia Museum, Adelaide, South Australia; Dr G.F. Gross. UZMC = Universitets Zoologiske Museum, Copenhagen, Denmark; the late Dr S.L. Tuxen. WAM = Western Australian Museum, Perth, Australia; Dr Terry Houston and Dr William Humphreys. ZMA = Zoologisch Museum, Universiteit van Amsterdam, The Netherlands; Mr Willem Hogenes.

Dr W.F. Humphreys of the Western Australian Museum sent me some cockroaches that were collected in caves on Christmas Island; among them was a male of what appeared to be a species of *Nocticola* but which I am placing here in a new genus.

SYSTEMATICS

Family Nocticolidae Bruner

*Metanocticola* gen. nov.

Type Species

*Metanocticola christmasensis* sp. nov.

Diagnosis


Etymology

The specific name refers to the metanotal setose
gland which is unique among cockroaches, and to the close association with *Nocticola* (see Remarks, below).

**Metanocticola christmasensis** sp. nov.

*Figures 1A, B*

**Material Examined**

**Holotype**

\(\delta\) (on slide), Christmas Island (Indian Ocean), BES 5769, Jedda Cave, Tb [troglobite] tree roots deep; Karst #CI 5, 29.iii.1998, S.M. Eberhard (WAM).

**Paratypes**


**Description**

**Male**

Small, eyeless. Pronotum suboval (Figure 1A). Tegmina elliptical, covered with minute setae, veins absent, length reduced reaching to about the third abdominal tergum. Hind wings absent (Figure 1A). Legs very long, slender, tibiae and tarsi similar in width, ventral margins of mid and hind femora without spines; anteroventral margin of fore femur with a row of minute dark setae (smaller than piliform sensillae), not all equal in length, terminating in a large spine (Figure 1B); genicular spines of femora, pulvilli and arolia absent, tarsal claws small, symmetrical, simple; basitarsi of all legs longer than the 4 other tarsomeres combined. Metanotum with a medial setose gland (Figure 1A); visible glands absent from all abdominal terga. Subgenital plate without styles, and genitalia *Nocticola*-like, with the genital hook on the left side (similar to those in *Nocticola adebratti* Roth; see Figures 3C and 3E in Roth and McGavin 1994). Colour, pale, whitish with a yellowish tinge.

**Female**

Resembles the male except for the absence of tegmina and metanotal gland.

**Nymph**

Resembles the wingless female.

**Measurements (mm)** *(? in parentheses; N = 1 \(\delta\), 1 ?)*

Length, 4.1 (4.4); pronotum length \(\times\) width, 1.1 \(\times\) 1.5 (1.1 \(\times\) 1.6); tegmen length, 1.6 (absent).

**Habitat**

The following information concerning Christmas Island and the caves in which the specimens were collected is from a letter (1998) from Dr William F. Humphreys: “Christmas Island (ca. 10°30’S, 105°40’E) is a sea mount closely surrounded by abyssal depths; its period of surface exposure is uncertain, probably since the early or mid-Pliocene (3–5 Ma), and possibly since the late Oligocene (26 Ma) (K. Grimes, pers. comm. in Humphreys and Eberhard 1998: 199). It is situated ca. 350 km south of Java, the closest land mass, and separated from it by the Java Trench. The extent of biological invasion is indicated by only 3.9% of the total flora being endemic to Christmas Island (Du Puy 1993: 12). The vegetation of Christmas Island has predominantly Indo-Malaysian affinities, with many species – all tolerant of limestone and alkaline soils – having distributions extending from southeast Asia through Malaysia to Australia (northeast Queensland), New Guinea and into the Pacific Islands (Du Puy 1993).”

“Jane Up Cave (karst index number CI-6) is a plateau cave containing an active streamway, sediment banks, tree roots, and troglobitic species. The cave is easily accessible, and there is some compaction of soft floor sediments and damage to tree roots. It is ca. 300 m from Jedda Cave (CI-5) and on the same streamway. The nocticolids were collected associated with tree roots.” Temperature, 25.5°–26.0°BOC; relative humidity, 96%; carbon dioxide, 3%; oxygen, 17–18%. The cave was very dry at the time of sampling as indicated by cracking sediments and at the end of a very dry period resulting from an El Niño Southern Oscillation event (ENSO). The cave is rated as of medium biological significance (possibly high if ENSO effect on fauna is marked) and as having medium vulnerability to caver impacts (Humphreys and Eberhard 1998).

**Remarks**

The unique male was placed in 10% KOH for 2 days, washed in water, dehydrated in alcohol, cleared in xylol, and mounted in Permount. Unfortunately the terminal segments (supra-anal and subgenital plates, and genitalia) were inadvertently lost after clearing, but I was able to note the characteristics of these structures. The description is based on the slide preparation, but the measurements were made before the specimen was cleared.

The habitus of *Metanocticola* is similar to the cavernicolous and epigean genus *Nocticola*, and cavernicolous *Spelaeoblatta* Bolivar. *Metanocticola* is the only cockroach, that I know, whose male has a sex gland on the metanotum. During courtship in *Blattaria*, male terminal glands attract the female to his back where she feeds or palpates the glandular region and is manoeuvred into the precopulatory position; while thus occupied, her movement is
arrested long enough for the male to grasp her genitalia. The male tergal gland(s) vary in their position, and one or more may occur on any abdominal segment and in various combinations (Roth, 1969). *Nocticola* males lack tergal glands or have them on the fourth abdominal segment only (Roth, 1988: 301). The male of *Spelaeoblatta thanifaranga* Roth, related to *Nocticola*, has visible glands on the second and third abdominal terga (Roth and McGavin, 1994, figures 2F, 2H).

Males of the cricket *Oecanthus pellucens* have a complex "alluring gland" on the metanotum similar to those on the abdomen of some male cockroaches (Engelhardt, 1914). However, no male tergal gland has previously been found on the metanotum of cockroaches and its presence in that position warrants placing the present species in a new genus.

**Family Blattellidae Karny**

**Subfamily Pseudophyllodromiinae Vickery and Kevan**

**Genus Supella Shelford**

*Supella* Shelford: Rehn, 1947: 59 (revision: divided *Supella* s.s. into three subgenera); Princis, 1969: 917.

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**Figure 1** *Metanoticola christmasetisis* sp. nov., male holotype from Christmas Island: A, head, thorax, abdominal segments 1–3, and tegmina; note the setose gland on the metanotum; B, foreleg (anterior surface).
Remarks

This is an African genus. Princis (1969: 917) listed four species in the subgenus *Supella*, three in *Nemosupella*, and one in *Mombuttia*.

*Supella (Supella) longipalpa* (Fabricius)

Supella supellectilium Servelle: Hebard, 1917: 47, pl. 1, figures 24–27; Rehn, 1947: 65, figures 1–8, pl. 1, figure 33; Roth, 1952: 469, figure 1; Pope, 1953, 23, 33, 37–40, 43–45, figures 1, 6d–h, 7.


**Material Examined**

**Burma:** Yenangyaung, Upper Burma, 600 ft., 5 δ, 3 η, 1 nymph, 27.viii.1937 (ANSP). Australia: Western Australia: Warburton Ranges, 1 δ, xii.1962, 1 δ, 23.vi.1963, 1 η, 18.xi.1962, M. DeGraaf; Landor Stn., 2 δ (1 with terminalia slide 13); Perth, 1 η, 31.i.1975, S.M. Wade, 1 δ, 22.v.1963, L. Smith, 2 δ, i-ii.1975, WAM staff, 1 nymph, 16.vii.1965, G.M. Riley; Wittenoom, 1 η; Perth (Greenwood), 2 η, 25.i.1977, P.G. Kendrick; Perth (Mt. Lawley), 1 η, vi.1975, F.C. Blakeley; from culture; Q.L.M.R., 1 δ, xii.1919, P. Pope (WAM); Broome, 4 η, 19, 1 nymph, 1.i.1964, Monash Univ. Zool. Dept. (ANIC). Queensland: Hamilton, 1 η, 5.xii.1949, H.M. Cane (WAM); Brisbane, 10 δ, 7 η; Ingham, 1 δ, 4.vi.1958, T. Campbell (ANIC). New South Wales: Wollongbar, 1 δ, 1 η, 5.i.1970; Sydney University, 1 δ, 11.viii.1964, J. Hewit; near Hillston, 4 δ, 2 η, 3 nymphs, invading several station cottages close to river bank, no damage, 20.iv.1972, P.P.B. Hillston; Menindee, 2 δ, in large numbers indoors, i.1972; Barradine, in house, 1 δ, vii.1954 (DARA).

**Redescription**

**Male**

Intercocular space less than distance between antennal sockets. Tegmina and wings fully developed extending beyond end of abdomen, the former with oblique discoidal sectors (Figure 2B). Hind wing with simple radial and media veins, cubitus vein with two or three complete, and one (long) or no incomplete branches, apical triangle subobsolete (Figure 2D). Front femur Type A2; pulvilli present on four proximal tarsomeres, tarsal claws simple, symmetrical, arolia present. First abdominal tergum unspecialized. Seventh abdominal with a large oval or suboval depression bearing dense groups of setae (Figure 2C). Subgenital plate trigonal, apex shallowly incised (seen best in flattened slide preparation, Figures 2E, F); styles cylindrical, similar (Figure 2F) each lying against the margin of the plate (in pinned specimen; Figure 2E). Genitalia as in Figure G: hook on the right side, slender, elongated, hook region small, with a preapical incision; median phallomere a curved rod with a small dark sclerite at its apex; left phallomere consisting of several irregular sclerites.

**Female**

Differs from male as follows: Eyes wider apart, interocular space about the same as distance between antennal sockets. Tegmina and wings reduced, not reaching end of abdomen (length may vary reaching from the fourth to the ninth abdominal segment). Seventh abdominal tergum unspecialized. Apex of supraanal plate with a slightly larger excision (Figure 2A).

**Colouration**

Head with occiput to below antennal sockets yellowish brown, face and genae suffused with dark brown. Pronotal disk and posterior border region yellowish brown, lateral borders hyaline. Tegmina hyaline with a pair of light brown regions, one proximal in the anal vein region, the other towards the middle and more extensive (Figure B), costal vein region tinged with yellow, the remaining regions almost colourless. Abdomen and legs yellowish brown. Some specimens are darker with occiput yellowish orange, pronotal disk deep chestnut brown, and tegminal markings a darker brown and more distinct. The colour markings on the pronotum and tegmina vary (in specimens from the same locality), from very faint or absent, to very dark.

**Measurements (mm) (? in parentheses)**

Length, 10.2–13.1 (9.7–13.5); pronotum length x width, 2.6–3.1 x 3.5–3.9 (2.9–3.3 x 4.0–4.3); tegmen length, 9.8–12.8 (6.8–8.1).

**Remarks**

This is an important, widely distributed, circumtropical, domiciliary pest. The oviposition behavior and site preference of this species has been studied by Benson and Huber (1989). The adult female produces a sex pheromone, principally in the fourth and fifth abdominal terga, released during calling behavior (Schal et al., 1992).

**Genus Mediastinea Hebard**


**Type Species**

*Aaplecta platycephala* Rehn, by original designation (Roach and Rentz, 1998: 159).

**Remarks**

Three species of *Mediastinea* have been
New cockroach species, mostly from Australia

Figure 2  *Supella longipalpa* (Fabricius), from Western Australia: A, female, terminal segments; B–G, males: B, tegmen; C, abdominal terga 7 (note tergal gland) to 10 and subgenital plate; D, hind wing; E, subgenital plate (ventral; pinned specimen); F, subgenital plate (ventral; slide preparation); G, genitalia (dorsal).

reported from Australia (Hebard, 1943). They are volant, foliage frequenters (Roach and Rentz, 1998: 160). The genus was revised by Mr John Strazanac (unpublished Master’s thesis at the University of Hawaii at Manoa). According to Strazanac, additional undescribed species occur outside of Australia, including New Guinea, Guam, Guadacanal, and Micronesia; he described at least seven new species in his thesis.
Mediastinea delicatula (Shelford)


Material Examined

Mediastinea platycephala (Rehn)


Material Examined

Remarks
The species is found in coastal northeast and southeast Queensland and New South Wales.

Genus Pseudobalta Roth


Type Species
Balta pusilla Hebard, by original designation (Roach and Rentz, 1998: 160).

Remarks
I recently erected this Australian genus to include three species, namely Balta pusilla Hebard, Balta cinctella Hebard, and Pseudobalta queenslandica Roth. The genus differs from its close relative Balta, by being ovoviviparous, and the males having a gland on the first abdominal tergum.

Pseudobalta cinctella (Hebard)

Balta cinctella Hebard, 1943: 58, pl. VIII, figure 2, pl. X, figure 8, pl. XII, figure 3 (♂ and ♀); Princis, 1969: 971.

Material Examined

Description
The female from Massy Ck. has tegmina and wings that do not quite reach the supraanal plate; the other female has similar tegmina but the wings are vestigial.

The species is found in Queensland, Northern Territory, Western Australia, and possibly South Australia and New South Wales.

Pseudobalta queenslandica Roth


Material Examined

Remarks
The only previous record was the West Cludie River, Queensland. The male is unknown. According to Dr Rentz’s notes, the species was taken in a rainforest with rather dense cover of trees on sandy soil in hilly terrain. The cockroaches probably were on low vegetation at night.

Genus Parectoneura Roth

Parectoneura Roth, 1990a: 652.

Type Species
Parectoneura bivittata Roth, by original designation (Roach and Rentz, 1998: 137, Parectoneura).

Remarks
Parectoneura is an Australian genus containing one species. Superficially it resembles Ectoneura (Ectobiinac), but belongs in the Blattellinae (Roth, 1990a: 661).

Parectoneura bivittata Roth

Figures 3A–F

Material Examined
Australia: Northern Territory: 2 ♂ (1 with terminalia slide 600), Goose Lagoon, 11 km SW. by S. of Boroloola, 16°10'S, 136°15'E, 18.iv.1976, Key, Balderson et. al., Key’s Field Notes – Trip 191, Stop 3614.8, 1 ♀, 31.x.1975, M.S. Upton (ANIC). I have also reexamined all the types from Northern Territory and Western Australia.

Description
The bands on the pronotum vary in intensity and
width and their margins may be sharply defined or diffuse (Figures 3A–C). The bands on the tegmina may be very dark and broad extending the full length of the forewing (Figure 3A in Roth, 1990a) or are lighter and variably reduced in length (Figure 3E). The male subgenital plate and genitalia of the Goose Lagoon specimens (Figure 3D) differ slightly from those of a male from Tindal, Northern Territory (see Figure 35D in Roth, 1990a).

Measurements (mm) (♀ in parentheses; N = 2 ♂, 1 ♀)

Length, 5.7 (7.0); pronotum length x width, 1.5 x 2.0–2.1 (1.5 x 2.2); tegmen length, 6.0–6.2 (5.8); interocular width, 0.5 (0.4); interantennal socket width, 0.5 (0.5).

Remarks

According to Dr Key’s notes, the cockroaches were collected in a variety of habitats adjacent to a lagoon, with *Eucalyptus papuana*, *Erythrina vespertilis*, and others. Other habitats were sandy ridges with Bloodwoods and *Eucalyptus dichromophloeoc*, Atalaya, *Erythrophloecum*, and *Acacia*.
Genus *Balta* Tepper

*Balta* Tepper, 1893: 39; Roach and Rentz, 1998: 147.

**Type Species**

*Balta epilamproides* Tepper, by monotypy.

**Remarks**

This is a very large genus in need of revision. There are a number of generic synonyms and whether *Balta* is the valid name is debatable; it may prove to be a junior synonym of *Lupparia*.

*Balta notulata* (Stål)

*Balta notulata* (Stål): Roth, 1990c: 366, figures 6, 7 (redescriptions: 6 and 7, synonymy, and distribution).


**Material Examined**

**Australia:** Christmas Island (Indian Ocean): Pinkhouse, 1 6, iv.1998, W. Humphreys (WAM); although previously never recorded from Christmas Island, the species has been collected in the Chagos Islands in the Indian Ocean (Roth, 1990c: 366).

**Papua New Guinea:** The following were collected by G. W. Beccaloni: Usini Village [5°32'S, 145°24'E], nr. Usino, Madang Prov., in house, 1 6, 1 6, 25.viii.1990; Awar nr. Laing Island [4°10'S, 144°52'E], Hansa Bay, Madang Prov., in bunch of bananas, 1 6 nymph (MCZ).

**Solomon Islands:** Eiland Florida (= Small Gela = Nggela) [9°05'S, 160°50'E], Dorp Belaga [9°04'S, 160°20'E], 1 6, xi.1963, rond dorp Belaga, 5 6, 4 6, 3 nymphs, 1963/1964, 1 6, 1966, 1 nymph, M.J.A. de Kosler (ZMA), two specimens retained in (MCZ).

**Philippine Islands:** Trinidad [12°03'N 124°32'E], Benguet, Luzon, 1 6, 17.x.1914, W. Boettcher (ANSP). Malaysia: Kota Tinggi, Johore, 1 6, viii.1917 (HECO).

**Remarks**

This is a very widespread and common species with distinctive facial markings and male genitalia (Roth, 1990c: Figures 6A, 7F). The tegmina have longitudinal discoidal sectors which bear nodes distally, and the spaces between the veins and cross veinlets are darkened giving a checkered appearance. The nymph has facial markings like the adult, but its pronotum has a solid dark brown macula on the anterior half of the disk, whereas the adult has a symmetrical pattern of dots, lines and small spots. I described the nymph (from Krakatau) as *Balta* sp. (Roth, 1990c: 371, Figure 81), but based on the present material I now conclude that it is the immature of *notulata*.

Beccaloni (1991: 507) trapped *Balta notulata* in houses in Papua New Guinea. He (1991), and Kevan and Kevan (1995: 227) claimed that the wide distribution of this species was due to their association with humans since individuals and oothecae could be disseminated between islands in the Pacific and Indian Oceans in various crafts.

Subfamily Blattellinae Karny

**Genus Neotemnopteryx** Princis

*Neotemnopteryx* Princis: Roth, 1990b: 535 (revision); Roach and Rentz, 1998: 118.

**Type Species**

*Temnopteryx ferruginea* Tepper (= *Ischnoptera fulva* Saussure) by monotypy.

**Remarks**

There are 11 species of *Neotemnopteryx*, a genus restricted to Australia. One of these, *N. wynnei* Roth from Western Australia, is the second cavernicolous species known in this genus (Roth, 1995: 158).

*Neotemnopteryx concava* Roth


**Material Examined**

**Australia:** New South Wales: 1 6, 12.xi.1956, G.A. Mulder (ZMA).

**Remarks**

This species also is known from Queensland and Western Australia, and is found under bark and litter.

*Neotemnopteryx australis* (Saussure)


**Material Examined**

**Australia:** Australian Capital Territory: Canberra, 1 6, 12.i.1959, W.J.M. Vestjens (ANSP).

**Remarks**

This species also has been taken in New South Wales, and occurs under bark and litter.

**Genus Paratemnopteryx** Saussure

**Paratemnopteryx** Saussure: Roth, 1990b: 560 (revision); Roach and Rentz, 1998: 120.

**Type Species**

*Paratemnopteryx australis* Saussure, by monotypy.
New cockroach species, mostly from Australia

Remarks
There are 10 named species in this Australian genus.

Paratemnopteryx sp. 1
Paratemnopteryx sp. 1 Roth, 1990b: 580, figures 26A–C (♂ and ♀).

Material Examined
Australia: Western Australia: Eneabba region, Cave E22, 1 ♂, 1.vi.1991, C. Rippon; N-W Cape Penin., Cave C79, 22.06S 14.00E, 1 ♂, 27.vi.1989, W.F. Humphreys and R. Wood, CR ’89 #3205 (WAM).

Remarks
This unnamed species combines characters of P. australis Saussure and P. rufa (Tepper). It was previously reported from Queensland (pitfall traps) and Northern Territory (bat caves). Its eyes are fairly well developed.

Paratemnopteryx centralensis (Roth)


Paratemnopteryx centralensis (Roth), 1990b: 584, figures 29A, B, 35; Roach and Rentz, 1998:121.

Material Examined

Remarks
This is an aberrant species whose styli are greatly reduced. It is also found in northern coastal Queensland and northeast coastal Northern Territory.

Genus Beybienkoa Roth

Type Species
Symplaco orinoaensis Roth, by original designation; Roach and Rentz, 1998: 123.

Remarks
There are 34 species of Beybienkoa, of which 24 occur in Australia, 10 are found in New Guinea (all of the New Guinea species were originally in Symplaco and two of these also occur in Australia). The genus was rediagnosed (Roth, 1999: 126) and a number of Australian species were transferred to Carbrunneria Princis (see below).

Beybienkoa kurandanensis Roth

Material Examined

Beybienkoa ilukanensis Roth
Beybienkoa ilukanensis Roth, 1991a: 695, figure 88 (♂ and ♀); Roach and Rentz, 1998: 125.

Material Examined

Genus Carbrunneria Princis
Carbrunneria Princis, 1954: 36.

Type Species

Remarks
After I rediagnosed Beybienkoa (Roth, 1999: 126), the following Australian species described by me, were transferred to the genus Carbrunneria: barrinensis, bicaudata, eachamensis, finniganensis, guttifera (= papuensis), lezoisensis, maxi, nettae, paramaxi, webbana, and windsorana.

The principal diagnostic character separating three closely related genera are the presence and location of the male tergal gland, or their absence. Beybienkoa has a gland on the first abdominal tergum, Carbrunneria has one on the seventh segment, and the gland is absent in Johnrehnia.

The gland in Carbrunneria consists of a fossa with or without setae. Those with setae are easy to distinguish. However, some of the species that lack setae may be difficult to place if the fossa is very shallow or hidden under the overlapping sixth tergum, and it may be necessary to make a slide preparation of the segment to determine its presence or absence.

I have almost completed my revision of Carbrunneria and Johnrehnia and find more than 40 species in the former and about 25 taxa in the latter.
Carbrunneria barrinensis (Roth)


Carbrunneria barrinensis (Roth): Roth, 1999: 126.

Material Examined

Carbrunneria guttifera (Walker)

Phyllodromia guttifera (Walker): Kirby, 1904: 93; Shelford, 1907b: 493; 1908a: 14.
Beybienkoa guttifera (Walker): Roth, 1997c: 102, figures 102–104.
Symploce papuensis Roth, 1985: 300, figures 1A–J.
Beybienkoa papuensis (Roth), 1991a: 656, figures 61, 64A–C; Roach and Rentz, 1998: 126.

Carbrunneria papuensis (Roth), 1999: 126.

Remarks
The species has been collected in Papua New Guinea, Queensland (Moa and Murray Islands), and the Moluccas (Aru Island). This volant taxon is found in litter and has been taken in closed forest, rainforest margins, mixed open low forest, in Malaise pan and pitfall traps, also by sweeping, and at light (Roach and Rentz, 1998: 126).

Genus Robshelfordia Princis


Type Species
Robshelfordia simplex Princis, 1954, by original designation.

Diagnosis

Male
Fully winged, tegmina with longitudinal or sublongitudinal discoidal sectors. Hind wings with simple radial, media, and cubitus veins, apical triangle present. Fore femur variable: Type A, Type B, or intermediate between Types A and B; tarsal claws symmetrical or asymmetrical. First abdominal tergum specialised; seventh abdominal tergum un specialised. Hooklike genital phal lomere on the left side.

Female
Tegmina and wings fully developed or tegmina reduced to lateral pads, hind wings absent.

Remarks
This Australian genus contains 12 species. The females of only five were known when the taxon was revised (Roth, 1991a) and these had small tegm inal pads and lacked hind wings, whereas the males were fully winged. In a new species described below both sexes have completely developed wings and their habitus is similar.

Robshelfordia fraserensis sp. nov.

Material Examined
Figures 4A–E

Holotype
♂, Fraser Island (25°15' S, 153°10' E), Central Station, Queensland, Australia, 19.xii.1979, at light, K.J. Lambkin (QM).

Paratypes
Australia: Queensland: same data as holotype, 2 ♂ (1 with terminalia slide 105), 4 ♀ (QM, 1 ♀ retained in the MCZ).

Description

Male
Interocular space about the same as the distance between ocellar spots, less than the distance between antennal sockets (Figure 4A); fifth maxillary palpomere longer than the fourth. Tegmina and wings fully developed extending beyond end of abdomen, the former with longitudinal or sublongitudinal discoidal sectors. Hind wing with simple radial, media, and cubitus veins, the latter without incomplete branches, apical triangle small (Figure 4E). Fore femur Type A3, B2, or intermediate between A and B; pulvilli on 4 proximal tarsomeres, tarsal claws simple, symmetrical, arolia present. First abdominal tergum with a pair of shallow nonsetose fossae. Seventh abdominal tergum unspecialised. Supra-anal plate hind margin convex, shallowly indented medially; paraprocts dissimilar, the left one with 2 spinelike sclerites, the right one a single spine structure (Figure 4C). Subgenital plate with a pair of dissimilar, widely separated styles, the left one conical, the right one small, stouter, subtrigonal, with a few small spines, interstylar margin straight (Figure 4D); in the pinned specimen, the right style is upturned and largely hidden under the supra-anal plate. Genitalia as in Figure 4D: hook on the left side, without a preapical incision; median phal lomere slender, simple, apically acute; right
New cockroach species, mostly from Australia

Figure 4 Robshelfordia fraserensis sp. nov., males: B from holotype, all others from a paratype: A, head; B, pronotum; C, hind wing; D, supra-anal plate and paraprocts (ventral).

Phallomere consisting of 4 sclerites, one a cleft and another with 4 large spines. Colour: Head dark brown, occiput, vertex, cheeks, and postclypeus may be lighter (Figure 4A); maxillary palpomeres 4 and 5 dark, segment 3 lighter; antennae light brown. Pronotum dark brown with a pale spot posteromedially, lateral and anterior borders opaque white (Figure 4B). Tegmina light brown, hyaline, humeral vein dark. Hind wing infuscated. Proximal abdominal terga pale, segments 7 to 9 dark, lateral borders and supra-anal plate pale. Abdominal sterna pale. Legs pale. Cerci pale dorsally, dark ventrally.

Female

Habitus similar to male. Tegmina and wings completely developed, venation as in male. Hind margin of supra-anal plate with oblique sides, the medial region weakly indented. Front femoral armament variable as in the male. The female abdominal tergum is darker and the lighter sternum has a large brown macula on the subgenital plate.

Measurements (♀ in parentheses; N = 3 ♂, 4 ♀; averages in brackets)

Length, 7.0–8.0 [7.5] (8.0–8.5) [8.2]; pronotum length x width, 1.6–1.7 x 2.5–2.6 [1.6 x 2.6] (1.7–2.0 x
Robshelfordia circumducta (Walker)


Material Examined


Remarks

The species is found in Queensland, New South Wales, Australian Capital Territory, Victoria and South Australia.

The male is winged and the female has reduced tegmina and lacks hind wings. The species is found in dry sclerophyll forest, under bark.

Genus Parasigmoidella Hanitsch


Type Species

Parasigmoidella marginalis Hanitsch, by monotypy.

Remarks

There are 35 described species of Parasigmoidella, 28 of which are found in New Guinea. Only one species, namely P. debilis (Hanitsch) is known from Australia (Marrakai, Northern Territory). The following new species is the second of the genus known to occur in Australia (Queensland).

Parasigmoidella atypicalis sp. nov.

Figures 5A–F

Material Examined

Holotype

♂, Davies Ck. (10.6 road km from Kennedy Hwy.), 17 km E. by S. of Mareeba, Queensland, Australia, 17°01'S, 145°35'E, 2.ii.1988, D.C.F. Rentz, Stop A–13 (ANIC).

Paratypes

Australia: Queensland: same data as holotype, 3 ♂ (2 with terminalia slides 655 and 669; first abdominal tergum slide 671) (ANIC).

Description

Male

Interocular space slightly less than the distance between antennal sockets (Figure 5A); fifth maxillary palpomere larger than the fourth. Pronotum subelliptical (Figure 5B). Tegmina and wings fully developed extending beyond end of abdomen, the latter with longitudinal discoidal sectors. Hind wing with radial and all costal veins simple, median vein curved, simple, cubitus vein curved, with one complete and 0 or 1 incomplete branches, apical triangle distinct (Figure 5D). Fore femur Type B2; pulvilli on 4 proximal tarsomeres, tarsal claws simple, symmetrical, arolia present. First abdominal tergum with a deep oval fossa containing 2 groups of dense agglutinated setae; in the pinned specimen the fossa appears to be nonsetose, but the setal nature of the dark spots is revealed when the first segment is cleared and mounted on a slide (Figure 5C). Supra-anal plate symmetrical, trapezoidal, paraprocts dissimilar, the left one with 2 spinelike processes, the right one with 3 processes (Figure 5F). Subgenital plate almost symmetrical, with one left cylindrical style, and two right dissimilar styles, one tapering, apically acute, the other almost contiguous, broad with 2 setae and a lateral projection, interstylar margin straight, greater than the length of the style (Figure 5E). Genitalia as in Figure 5E: hook on the left side, without a preapical incision, median phallomere curved distally, apex pick-axe-like, right phallomere consisting of about 4 sclerites, one a cleft, and 2 with one and 3 spines. Colouration: Head (including occiput, vertex, and cheeks black, anteclypeus and ocellar spots pale (Figure 5A); maxillary palpomeres mostly dark; antennae dark. Pronotal disk black, completely surrounded by a white, opaque border (Figure 5B). Tegmina reddish brown, darker basad, anterior margin pale (a continuation of the pale pronotal border). Hind wing with anterior field and region behind the apical triangle weakly darkened (Figure 5D). Abdominal terga brown, lateral edges whitish. Abdominal sternal light brown medially with broad, dark brown lateral bands. Legs light brown, coxae with outer margins narrowly darkened; femora with dorsal and ventral margins dark. Cerci dorsally with proximal segments dark, remainder lighter, ventrally completely dark.

Female

Unknown.

Measurements (mm) (N= 2 ♂)

Length, 7.7–8.0; pronotum length x width, 1.8 x 2.7; tegmen length, 8.2–8.5; interocular width, 0.5.
New cockroach species, mostly from Australia

Figure 5  *Parasigmoidella atypica* sp. nov., male paratype: A, head; B, pronotum; C, first abdominal tergum; D, hind wing; E, subgenital plate and genitalia (dorsal); F, supra-anal plate and paraprocts (ventral).

Remarks
Hind wing venation and the sexual gland on the first abdominal tergum places this species in *Parasigmoidella*, and its symmetrical supra-anal plate assigns it to the spinifera species-group (Roth, 1997b: 151). However this taxon is atypical of the genus because its two right styles, paraprocts, and right genital phallomere resemble those found in some species of *Carbrunneria* Princis. Its habitus also resembles *Carbrunneria jocosa* (Shelford) and *Johnrehnia concisa* (Walker).
Etymology
The specific name refers to the fact that the species is atypical for the genus; see Remarks.

Parasigmoidella mayriverana sp. nov.
Figures 6A-C

Material Examined
Holotype
δ (terminalia and first abdominal tergum slide 578), May River, NE. New Guinea [Papua New Guinea], 100 m, light trap, 8.vi.1963, R. Straatman (BPBM).

Description
Male
Interocular space slightly less than the distance between antennal sockets; maxillary palpomeres 4 and 5 about equal in length. Pronotum suboval. Tegmina and wings fully developed extending beyond end of abdomen, the former with longitudinal discoidal sectors. Hind wings with simple costal veins, radial vein straight, simple, median vein curved, simple, cubitus vein curved, with 1 complete and 1 incomplete branches, apical triangle distinct. Fore femur Type B2, with 3 large proximal spines and a long row of piliform spinules; pulvilli apparently absent, tarsal claws simple, symmetrical, arolia present. First abdominal tergum with a medial setose gland (Figure 6A). Supra-anal plate transverse, hind margin with a broad excavation; paraprocts dissimilar, elongated, the right one very slender (Figure 6B). Subgenital plate asymmetrical. Styles small, cylindrical, with a few small spines, widely separated, interstyilar margin without a process and shallowly indented near the left style (Figure 6C). Genitalia as in Figure 6C: hook on the left side, without a preapical incision, hook portion elongated, slender; median phallomere simple, apex acute; right phallomere a long slender rod and at least 2 setose sclerites.

Female
Unknown.

Measurements (mm) (N = 1 δ)
Length, ca 8.0; pronotum length x width, 2.1 x 2.9; tegmen length, 7.5; interocular width, 0.5.

Remarks
The species belongs in the spinifera species-group. The shapes of the supra-anal plate and paraprocts are similar to those of Parasigmoidella stylisimila Roth (cf. Figure 6B with Roth, 1997b, Figure 10C). However, their subgenital plates and genitalia differ (cf. Figure 6C with Roth, 1997b, Figure 10D).

Parasigmoidella milleri Roth
Figures 6D, E

Material Examined
Papua New Guinea: Chimbu Province, Haia, 6°41'S, 141°00'10"W, 1 δ (terminalia slide 478), 15.x.1987, Andrew Mack; (ANSP).

Remarks
This male differs slightly from the specimen illustrated in the original description. The left paraproct consists of three sclerites, one strongly curved and distally with several long setae (cf. Figure 6D with Figure 1C in Roth, 1997). The left style has only a small spine in each corner of the distal margin (Figure 6E) whereas the specimen illustrated in Figure 1E (Roth, 1997) has a row of serrations.

Measurements (mm)
Length, 10.8; pronotum length x width, 2.7 x 3.3; tegmen length, 11.5; interocular width, 0.7.

Subfamily Ectobiinae Chopard
Genus Choristima Tepper
Choristima Tepper: Roth, 1992a: 121 (revision); Roach and Rentz, 1998: 141.

Type Species
Blatta hydrophoroides Walker, by subsequent designation by Kirby 1904.

Remarks
This is an Australian genus containing 13 species, most of them occurring in the eastern part of the continent; one species is found in Tasmania.
New cockroach species, mostly from Australia

Figure 6  *Parasignoidella* spp., males. A–C, *P. mayriverana* n.sp. holotype: A, first abdominal tergum; B, supra-anal plate and paraprocts (ventral); C, subgenital plate and genitalia (dorsal). D–E, *P. milleri* Roth from Haia, Chimbu Prov., Papua New Guinea; D, supra-anal plate and paraprocts (ventral); E, subgenital plate and genitalia (dorsal).

volant, found under bark litter, and taken in light traps (Roach and Rentz, 1998: 143).

*Choristima galericoides* (Walker)


Material Examined


Remarks

The species also is known from Victoria, South Australia, and Australian Capital Territory.

*Choristina bimaculata* Roth

*Choristina bimaculata* Roth, 1992a: 141, figures 12, 15 (♂ and ♀); Roach and Rentz, 1998: 142.

Material Examined

Australia: Queensland: Split Rock, 14 km S. of Laura [15°34'S, 144°28'E], N. Qld., 1 ♂, 23-26.vi.1975, G.B. Monteith; Hinchinbrook Island [18°23'S, 146°17'E], Gayundah Ck. [18°22'S, 146°12'E], 10 ♂, 1 ♀, 2–15.xi.1984, Monteith, Cook, and Thompson (QM); Davies Ck. (10.6 road km from Kennedy Hwy), 17 km E. by S. of Mareeba, 17°01'S, 145°35'E, 1 ♂, 2.i.1988, D.C.F. Rentz, Stop A–13 (ANIC). Western Australia: 3.8 km NE. of Comet Vale Siding, 29°37'S, 121°07'E, at light at night, 1 ♂, 7–15.iii.1979, T.F. Houston et al. 256–8, Western Australia Museum, Biol. Survey Site, G.G. Camp (WAM).
Remarks
This species, previously known only from the northeastern coast of Queensland, is the first record for Western Australia.

Choristima brunnea (Hanitsch), comb. nov.
Chorisoncura brunnea Hanitsch, 1934: 112, 126, figure 5 (♂).

Choristima sonjae Roth, 1992a: 131, figures 6, 7 (♂);

Material Examined
Holotype
♂, Chorisoncura brunnea Hanitsch, Burnside, Northern Territory, Australia, iv.1931, Handschin (with a handwritten label Chorisoncura brunnea, n. sp., ♂, R. Hanitsch, 6.vii.1933 (NHMB).

Additional material examined
Australia: Western Australia: Calm Site 13/4, 12 km S. of Kalumburu Mission, 14°25'S, 126°36'E, 1 ♂, at light open forest, 7–11.vi. 1988, T.A. Weir (ANIC).

Measurements (mm)
Pronotum length x width, 1.2 x 1.9; tegmen length, 4.4; interocular width, 0.3; ocular width, 0.5.

Remarks
When I described Choristima sonjae, I had not seen Hanitsch’s Chorisoncura brunnea. The types of both species were taken in Burnside, Northern Territory. It has also been taken in northeastern Queensland. This is the first record from northeastern Western Australia.

Hanitsch originally described this species in Chorisoncura. A recent revision of the genus (Roth, 1998: 1) has shown that Chorisoncura Brunner is a New World genus (South and Central America, and the United States), whereas Asian “Chorisoncura” belong in Sorineuchora Caudell which has been considered to be a synonym of Chorisoncura. African species of “Chorisoncura” belong in Chorisonuroides Princis.

Choristima astylata Roth

Material Examined
Australia: Western Australia: 145 km SE by E of Broome, 18°55'S, 123°27'E, 2 ♂, 7.viii.1976, I.F.B. Common (ANIC).

Remarks
One male was unusual in having a small style, a structure generally absent in this species. The species is found in the northeastern part of Western Australia, as well as the northern and south central parts of the Northern Territory.

Choristima tenebrica Roth
Choristima tenebrica Roth, 1992a: 149, figures 10, 21A–D (♀); Roach and Rentz, 1998: 143.

Material Examined
Australia: Australian Capital Territory: Blundell’s Ck., 3 km E. of Picadilly Circus, 850 m, flight intercept window trough trap, 1 ♀, ii.1984, 1 ♀, vi.1984, Weir, Lawrence, and Johnson; Blundell’s, 1 ♀, 23.i.1953, 1 nymph, 5.xii.1953, H.M. Cane (ANIC). New South Wales: Barrington Tops, 1 ♀, 6–10.iv.1949, H.M. Cane; Durras north, near Bateman’s Bay, 1 ♀, 8.x.1979, H.M. Cane (ANIC). Victoria: Mt. Buffalo N.P., 900 m, pyrethrum spray, Eucalyptus, 1 (abdomen missing), 18–19.i.1980, A. Newton, M. Thayer (ANIC).

Remarks
This is a volant species whose male is unknown. The females are found under bark litter. The present specimen is the first record from Victoria.

Genus Stenectoneura Hebard

Remarks
Hebard (1943: 27) placed four species in this Australian genus. Princis (1965: 352) listed two additional taxa under Stenectoneura, namely Blatta marcida Erichson and Apolyta titura Tepper, with a query. The former species is listed under Stenectoneura in Roach and Rentz’s catalogue (1998: 146). The latter species is a Balta (Roth, 1991b: 967).

Stenectoneura figurata (Shelford)
Figures 7A–G
Ectoneura figurata Shelford, 1907a: 43 (♂).
Stenectoneura figurata (Shelford): Hebard, 1943: 28;

Material Examined
Lectotype (here designated)
♂, no locality data (presumably Australia); Type Orth. 221/4 (HECO).
Figure 7  Stenectoneura figurata (Shelford), males, locality unknown, presumably Australia: A, head; B, pronotum; C, top of head; D, E, seventh abdominal tergum showing the glandular area; F, supra-anal plate and paraprocts (ventral); G, subgenital plate and genitalia (dorsal). Figure B, from lectotype, all others from a paralectotype.
Paralectotypes

Additional material examined

Redescription

Male
Interocular space slightly less than distance between antennal sockets (Figure 7A). Pronotum deplanate, subelliptical, widest behind the middle (Figure 7B). Tegmina and wings fully developed, the former with oblique discoidal sectors. Hind wing with costal veins slightly thickened distad, apical triangle curled when at rest. Front femur with no large proximal spines or row of piliform spinules, with two large terminal spines (Type D2). Hind margin of sixth abdominal tergum arched over the specialization on the seventh segment which consists of a depression whose anterior border is sclerotized and containing a group of small setae (Figures 7D, 7E; details are visible clearly in slide preparations and under high magnification). Supraanal plate with hind margin shallowly trigonal; right and left paraprocts poorly defined irregular sclerites (Figure 7F). Subgenital plate elongate, apex broadly rounded, right and left paraprocts poorly defined irregular sclerites (Figure 7F). Subgenital plate elongate, apex broadly rounded, right and left paraprocts poorly defined irregular sclerites (Figure 7F). Subgenital plate elongate, apex broadly rounded, right and left paraprocts poorly defined irregular sclerites (Figure 7F). Subgenital plate elongate, apex broadly rounded, right and left paraprocts poorly defined irregular sclerites (Figure 7F).

Female
Unknown.

Measurements (mm)
Length, 5.8–7.8; pronotum length width, 1.3–1.4 x 1.8–1.9; tegmen length, 6.5–7.6.

Remarks
This species was previously recorded only from Wallacia, New South Wales but probably is more widely distributed if my identification of the specimen from Western Australia is correct; the pronotal disk macula has less dark brown, but the five posterior spots on the pale background are present. Shelford (1909: 141) synonymized Stenecoteura punctatissima with S. figurata and S. margarita and recorded a male from Boorabbin, southwestern Australia. However, Hebard (1943: 29) believed both species to be closely related, but distinct.

Genus Theganopteryx Brunner


Type Species
Ectobia/Theganopteryx lucida Brunner, 1865, by monotypy.

Diagnosis (from Kumar and Princis, 1978: 19)
Tegmina usually fully developed generally extending beyond end of abdomen, rarely reduced. Hind wing between Cul+3A with an apical field which is involuted when at rest; Cul, lA and 2A reach the wing margin, rarely does Cu2 merge into Cu1. Front femur Type B2, tarsal claws symmetrical, unspecialized, arolia present. Male abdominal terga usually specialized, rarely unspecialized; the glands often are on the seventh tergum but they may occur on others such as second, third, fifth, or eighth, and rarely on the second and seventh segments.

Remarks
Based on my examination of the type species and descriptions of other species in Kumar and Princis, I add the following characters: Male supra-anal plate symmetrical or asymmetrical. Subgenital plate rarely symmetrical, usually asymmetrical but distally not tapering to a rounded apex (as in the Ectobiinae). One (rarely) or two styles are present, if the latter they are generally dissimilar. Male genital hook on the left side, greatly elongated, with a preapical incision, median phallomere a slender rod, right phallomere consisting of two sclerites, one a slender rod the other a reduced cleft.

According to Kumar and Princis this is an African genus and the records of a number of species from other countries are questionable.

Princis (1971: 1119) placed Theganopteryx in
Ectobiidae: Theganopteryginae. The greatly elongated male genital hook and the relatively simple median phallomere of this genus are somewhat similar to those found in Blattellidae, Ectobiinae: Ectobii. However, there are fewer sclerites composing the right phallomere, the shape of the subgenital plate does not taper to a rounded apex, and the positions of their tergal glands are more variable. For this reason I place Theganopteryx in the Blattellidae, Ectobiinae: Theganopterygini. Based on the variation in the male tergal glands, it is quite possible that more than one genus may be represented among the species now placed in Theganopteryx. A study of the internal male genitalia now placed in this taxon, might help to clarify this suggestion.

There is a question as to the correct determination of lucida, the type species of the genus. Shelford (1913: 645) studied Brunner's type which he borrowed from the Stettin Museum. The specimen lacked the abdomen so its sex was unknown but Shelford claimed that he recognized a series of specimens as being conspecific with it, and his description of the male was based on this material. Kumar and Princis (1978: 25) accepted Shelford's description of what he believed to be lucida because the type specimen "...is now in all probability lost,..." Even if Brunner's specimen (lacking an abdomen) were available it would not be of much help in identifying the species because other members of the genus have pronota with a pair of longitudinal bands. Shelford described the male's supra-anal plate as "...triangular, subtruncate at apex; subgenital plate lamina asymmetrical, notched to the left of the middle line, left style long and slender, right style absent." This does not agree with the supra-anal plate and the styli of the above specimens of lucida (which has two styles).

**Theganopteryx lucida Brunner**

Figures 8A-G

Ectobius/Theganopteryx lucida Brunner, 1865: 62 (sex unknown, abdomen missing). (Brunner described the species in Ectobius but listed it in his index under Theganopteryx. He gave the locality as "?Nouvelle Holland" [= ?Australia]; the genus has never been recorded from Australia, and apparently is restricted to Africa.


**Material Examined**

**Tanzania:** Tanganyika Terr., Rukwa Dist., Tumba, on light, 1 δ (terminalia slide 422), 22.xi.1950, H.O. Backlund; Tanganyika Terr., Ukerave Isl., 1 δ, 1 9, Father Cornad (ZILS). **South Africa:** Transvaal, Louis Trichardt, 2 δ, 20–30.xii.1956, A.L. Capener (ZILS). Cameroon: Afr. Fr., Kamerun, Yound., 1 δ, 2.vi.1952, J. Rageau (ZILS). All of these specimens were reported by Kumar and Princis (1978: 27) as lucida. One specimen retained in (MCZ).

**Redescription**

**Male**

Head almost hidden, interocular width slightly less than the distance between ocellum spots. Pronotum suboval (Figure 8A). Tegmina and wings fully developed extending beyond end of abdomen, former with simple radial vein and longitudinal discoidal sectors. Hind wing with simple costal veins almost all of them thickened, radial vein simple, convex, media vein simple, concave, space between the two veins broad in middle, tapering at each end, their cross veins decidedly longer in the middle than at both ends; cubitus vein concave with a single branch reaching the anterior margin of the apical triangle where it curves obliquely to meet the cubitus forming an elongated cell, apical triangle distinct, involuted when at rest; in the female (Figure 8G) the cubitus does not quite reach the apical margin and its branch does not join the cubitus. Front femur Type B2, with two or three large proximal spines; pulvilli on four proximal tarsomerers of all legs, arolia present. First abdominal tergum unspecialized. Seventh abdominal tergum with a huge deep depression containing a dense group of raised setae mesad (Figure 8D). Supra-anal plate symmetrical, hind margin weakly undulate, paraprocts dissimilar, right one larger (Figure 8C). Subgenital plate weakly asymmetrical with pair of widely separated dissimilar styli, right one cylindrical, left one spine-like, interstyal margin truncate (Figure 8E); The left style is hidden within the margin of the plate and is not visible in ventral view (Figure 8F) but is clearly seen in end view (Figure 8B). Genitalia as in Figure 8E: hook greatly elongated, on left side, with preapical incision; median phallomere rodlike apically weakly modified with three slender spinelike processes; right phallomere consisting of two sclerites one a slender rod, other a reduced cleft. Head uniformly yellowish brown, or reddish brown with clypeus and labrum paler, or mixture, region above antennal sockets lighter than the lower part; maxillary palpi pale, segment five darker; antennae brownish. Pronotum with light or dark reddish brown oblique stripes separated by yellowish zone, lateral region subhyaline pale (Figure 8A). Tegmina yellowish-hyaline, lateral margins pale, or reddish brown-hyaline with anterior and posterior regions lighter. Abdominal terga light yellowish brown. Abdominal sterna reddish brown with pale yellowish brown edging. Cerci brown. Coxae infuscated, remaining leg parts straw coloured.
Figure 8  *Thecanopteryx lucida* (Walker). A–F, males: A, pronotum; B, supra-anal and subgenital plates, and styles (end view); C, supra-anal plate and paraprocts (ventral); D, abdominal terga seven to ten (note gland on the seventh segment); E, subgenital plate and genitalia (dorsal); F, subgenital plate (ventral); G, female, left hind wing. Figures A, B, D, F, from Transvaal, C, E, from Tanganyika, G, from Cameroon.
New cockroach species, mostly from Australia

Female
Tegmina and wings reaching only to end of abdomen. Hind wing with cubitus not quite reaching edge of wing, and the branch not quite reaching the cubitus (Figure 8G). Hind margin of supra-anal plate convexly rounded reaching to hind margin of subgenital plate. Head light reddish brown, clypeus and occiput paler yellowish. Pronotal bands very dark. Tegmina reddish brown hyaline shading into lighter anterior and posterior regions. Abdominal terga brown, darker laterally, edges narrowly yellow. Abdominal sterna dark reddish brown, lateral margins yellow. Legs with coxae mostly reddish brown, remaining parts brownish yellow. Cerci brown.

Measurements (mm) (♀ in parentheses)
Length, 7.8–8.5 (7.5); pronotum length x width, 1.8–2.1 x 2.5–3.0 (2.0 x 2.8); tegmen length, 8.2–9.3 (6.5); interocular width, 0.4 (0.5).

Remarks
The tergal modification of *Theganopteryx heterogamia* Princis (Princis, 1963a: figure 62) is superficially similar to that found in *lucida*, but according to Kumar and Princis (1978: 27) the gland areas are microscopically different.

Family Blaberidae Brunner
Subfamily Epilamprinae Saussure and Zehntner
Genus *Laxta* Walker

Remarks
There are 13 described, and several unnamed species of *Laxta* in Australia. Two undetermined species occur in New Guinea. Some of the species are difficult to identify because their male genitalia are very similar; females of some species are particularly difficult to determine because sexual dimorphism is very strong (males winged, females aperous) making associating the sexes difficult.

*Laxta granicollis* (Saussure)
*Laxta granicollis* (Saussure): Roth, 1992b: 392, figures 1-3, 4A, B, 5, 6 (redescriptions: ♂ and ♀); Roach and Rentz, 1998: 94.

Material Examined
Australia: Victoria: Chiltern, under bark of *Eucalyptus*, 6 ♀, 1 ♀ nymph, 15-30.v.1966, 1 ♀ nymph, 3.vi.1966, W.H. Gravestein (ZMA). New South Wales: The following were collected by C. and A. Jeekel: 4 km E. of Marulan, 35 km WSW. of Moss Vale, 1 ♂, 1 ♀, 6.xi.1980, St. 66; Kosciusko Nat. Park, Larry’s Creek between Kiandra and Cabramurra, 35 km WNW of Adaminaby, St. 75, 1 ♀, 10. xi.1980; 5 km SW of Bungendore, 20 km ENE of Queanbeyan, 1 ♀, 7. xi.1980, St. 67 (ZMA); no exact locality: 4 ♂, 1 ♀, Crampton (MCZ).

*Laxta guttata* Roth
*Laxta guttata* Roth, 1992b: 419, figures 11, 18 (♂ and ♀); Roach and Rentz, 1998: 95.

Material Examined
Australia: Queensland: Eungella Natn. Park, 5 km N. of Netherdale, St. 30, 1 ♀, 18.x.1980, C. and A. Jeekel (ZMA).

*Laxta granulosa* Roth

Material Examined
Australia: New South Wales: The following were collected by C. and A. Jeekel: near Lake Glenbawn, 12 km ESE of Scone, St. 62, 2 ♂, 1 ♀, 1.xi.1980; Arding, 9 km NNE of Uralla, St. 58, 3 ♀, 31. x.1980; 20 km NNE. of Guyra, St. 57, 2 ♀, 1 ♀ nymph, 30.x.1980 (ZMA).

*Laxta tillyardi* Roth

Material Examined
Irian Jaya: Ifar [an agricultural station that lasted for ten years in Dutch New Guinea, 2°33’S, 140°34‘E], 1 ♂, xii.1957, G. den Hoed (ZMA).

Remarks
This is an Australian species found along the east coast of Queensland, as far north as the tip of the Cape York Peninsula, and on Moa (Banks) Island in the Torres Straits (Roth, 1992b: 411, figure 15). The new record is the first for New Guinea.

*Laxta feroculotacta* Roth

Material Examined
Australia: Queensland: The following were collected by C. and A. Jeekel: 16 km N. of...
Ravenshoe, 1♀, St. 14, 1♀, 8.xi.1980; Lake Barrine Nat. Park, 23 km SW. of Gordonvale, St. 17, 1♀, 9.x.1980; 5 km N. of Kuranda, St. 18, 1♀, 10.x.1980 (ZMA).

Genus Molytria Stål


Type Species

Epilampira inquinata Stål, by monotypy.

Remarks

There are three species of Molytria, including a new one described below, found only in Australia. They can be distinguished in the following key:

1. Males. Tegmina and wings fully developed.  
   Females. Tegmina reduced. Hind wings vestigial (Figures 9A,D) ......................... 4

2. Tegmina and wings extending well beyond end of abdomen.  
   Tegmina not reaching the end of the abdomen.  
   Pronotal disk pictured ........................ M. perplexa

3. Large: Pronotum length x width, 7.1-9.1; tegmen length, 31.5. Pronotal disk with a broad dark solid macula............ M. inquinata
   Smaller: Pronotum length x width, 5.4-5.7 x 7.4-7.8; tegmen length, 19.6-22.0. Pronotal disk pictured (Figure 10B) .......... M. vagranda

4. Pronotal disk with a solid dark macula reaching the anterior and posterior margins (Figure 9A). Tegmina with distal margin broadly rounded reaching about the third segment (Figure 9A).  
   Pronotal disk pictured with a symmetrical blackish macula Figures (9D, 10B). Tegmina reaching the first abdominal tergum, distal margin subtruncate, corners rounded (Figure 9D) ......... 5

5. Large: Tegmen length, 6.8-8.7; interocular width, 2.3-2.6 ........................ M. perplexa
   Smaller: Tegmen length, 5.2-6.4; interocular width, 1.9-2.1 ........................ M. vagranda

Molytria inquinata (Stål)

Figures 9A–C

Epilampira inquinata Stål: Shelford, 1910: 7, pl. 1, figure 8 (♂ habitus); Princis, 1967: 647 (literature and synonymy); Roach and Rentz, 1998: 97.

Material Examined


Redescriptions

Male

Head hardly exposed, interocular space greater than the distance between ocellar spots, about the same as width between antennal sockets. Pronotum subparabolic, sides deflexed. Tegmina and wings fully developed extending well beyond end of abdomen. Anteroventral margin of front femur with six or seven small stout spines succeeded by a short row of piliform spinules, terminating in a single large spine; pulvilli on four proximal tarsomeres of all legs; hind metatarsus about as long as the succeeding segments, its pulvillus elongated towards the base beyond the middle of the segment where there are only a few small spines in a short double row; tarsal claws simple, symmetrical, aroliia small. Abdominal terga unspecialized; posterolateral corners of the segments rounded. Supraanal plate with hind margin convexly rounded, entire, paraprocts large, dissimilar "hairy" plates; cerci extend beyond hind margin of the subgenital plate (Figure 6B). Exposed portion of the subgenital plate transverse, styles similar, widely separated, interstyal margin shallowly convex (Figure 9C). Genitalia as in Figure 9C: hook on the right side, sclerotized portion short, apex blunt, without a preapical incision; median phalomere wide at base, tapering distad, apex with a small, densely setose lobe; left phalomere a large cleft sclerite. Head with yellowish occiput and small dark dots, vertex with a large medially interrupted brown macula, rest of face lighter, clypeus and labrum yellowish; proximal antennomeres becoming yellowish distad. Pronotal disk with a large dark essentially uniform reddish brown macula, its lateral margins uneven, broad lateral and narrow anterior regions yellowish with some large and more numerous small dark dots (as in Figure 6A). Tegmina yellowish with large areas mottled reddish brown, humeral vein darker. Hind wings with yellowish tinge. Abdominal terga divided transversely into anterior light brown and posterior darker brown bands. Abdominal sterna dark reddish brown with medial and lateral
regions of proximal segments yellowish and speckled with dark dots. Legs brownish yellow.

Female

Tegmina reduced in length reaching to about the third abdominal tergum, apical outer corner broadly rounded, width normal the hind margins contiguous (Figure 9A). Hind wings shorter and narrower, reaching to about the second abdominal tergum, veins present (Figure 9A). Pulvillus of hind metatarsus extending beyond the middle of the segment where there is a very short double row of spines. Posterolateral corners of the abdominal terga obtuse or in the form of a small spine. Supraanal plate with an incomplete longitudinal groove, hind margin convexly rounded, entire, or shallowly indented. Cerci are small and do not reach the hind margin of the subgenital plate. Head usually with more extensive dark regions. Abdominal terga with large mottled areas of dark dots, longitudinal stripes and blotches on a yellowish background. Subgenital plate and preceding segment dark brown or dark reddish brown, remaining segments with large medial and lateral areas yellowish, the lateral regions with numerous small dark dots.
Measurements (mm) (♀ in parentheses)

Length, 26.0 (26.0–33.0); pronotum length x width, 7.1 x 9.1 (7.2–8.1 x 10.4–12.0); tegmen length, 31.5 (9.0–13.0); interocular width, 1.6 (2.2–2.3).

Remarks

This species has been recorded from South Australia, Victoria, and Tasmania.

Molytria perplexa Shelford

Figures 9D–F

Molytria perplexa Shelford, 1910: 7, footnote 1 (♂);

Material Examined

Holotype

♀ (terminalia on slide), Gippsland, Victoria, Australia (with the following handwritten labels: "28. Epilampra inquinata Stål, Gippsland 3/95", "det. by Tepper 3/95", "Det. by Shelford, sent ...1907", Type T-4443) (NMV).

Additional material examined


Redescription

Male

Head exposed. Pronotum subparabolic. Tegmina with rounded apex, slightly reduced, reaching to seventh abdominal segment, wings with truncate apex reaching the middle of tergum six. Anteroventral margin of front femur with five large proximal spines succeeded by about eight, well spaced piliform spinules terminating in a single large spine; mid and hind tarsi missing. Abdominal terga unspecialized, hind margins with small, well spaced ridges. Supraanal plate with hind margin convexly rounded, reaching the upturned hind margin of the subgenital plate. Median genital phallosome very darkly sclerotized and with a small setose structure apically (Figure 9F); right genital hook with a small sclerotized hook portion, apically truncate (Figure 9F). Head reddish brown, with a large black macula extending from the vertex to the level of the antennal sockets. Pronotum black, lateral zones with small and large black dots on a yellowish background (similar to the female, Figure 6D but usually more intense or distinct). Tegmina reddish brown, costal areas brownish yellow, mediastinal vein black.

Female (previously undescribed)

Head slightly exposed, interocular space greater than the distance between ocellar spots, about the same as the space between antennal sockets. Pronotum subparabolic hind margin weakly produced medially (Figure 9D). Tegmina width normal, length reduced, hind margin unevenly truncate, corners narrowly rounded, reaching the first abdominal tergum (Figure 9D). Hind wing vestigial, reaching the first segment, its posterior field subobsolete (Figure 9D). Anteroventral margin of front femur with three to five stout spines, succeeded by a row of minute piliform spinules, terminating in one (sometimes two) terminal spines; posteroventral margin of the front femur and both ventral margins of the mid and hind femora usually with less than four spaced spines; pulvilli on four proximal tarsomeres of all legs; fore and mid metatarsi short, without ventral spines, hind metatarsus longer, its pulvillus extending to before the middle of the segment where there is a relatively long double row of small spines that do not quite reach the base of the tarsomeres; tarsal claws symmetrical, simple, arolia small. Posterolateral corners of all abdominal terga not produced, supraanal plate with hind margin convexly rounded, shallowly indented mesad. Cerci short, not reaching hind margin of supraanal plate. Head with vertex dark brown becoming reddish brown below the ocellar spots until the proximal half of the clypeus, the distal half and labrum yellowish. Pronotal disk mottled dark reddish brown (the intensity and amount of mottling may vary), lateral and anterior border regions yellowish brown with large and small dark brown dots. Tegmina reddish brown with brownish yellow mottling, radial vein dark reddish brown. Abdominal terga dark brown mottled with brownish yellow. Abdominal sternum with broad medial area reddish brown, lateral zones very dark brown to black, subgenital plate blackish except for a small reddish brown area anteromedially. Cerci yellowish, apex black. Legs reddish brown.

Measurements (mm)

Length, 25.7–28.0; pronotum length x width, 6.9–7.4 x 10.4–11.0; tegmen length, 6.8–8.7; interocular width, 2.3–2.6.

Remarks

Apparently this is the first record of the species from New South Wales, previously being known only from the type male from Victoria.
New cockroach species, mostly from Australia

*Molytria vegranda* sp. nov.

Figures 10A–D

Material Examined

**Holotype**


**Paratypes**


![Image](A.png)

![Image](B.png)

![Image](C.png)

![Image](D.png)

Figure 10  *Molytria vegranda* sp. nov., male paratypes from New South Wales. A, B, D, from Bawley Point, C from Jervis Bay: A, head; B, pronotum (pale form); C, supra-anal plate and paraprocts (ventral); D, subgenital plate and genitalia (dorsal).
Male

Head with interocular space greater than the distance between ocellar spots and less than the width between antennal sockets (Figure 10A); fifth maxillary palpomere longer than the fourth. Pronotum subelliptical, widest behind the middle, hind margin weakly produced medially (Figure 10B). Tegmina and wings fully developed extending beyond the end of the abdomen. Hind wing cubitus vein with 2 complete and about 6 incomplete branches, apical triangle absent. Anteroventral margin of forefemur with 4 large proximal spines succeeded by a row of about 6 small, well spaced piliform setae, terminating in a single large spine (rarely with an additional small terminal spine); pulvilli on 4 proximal tarsomeres, the one on the basitarsus of the hind leg extending about two thirds the length of the segment where about 6 to 14 setae are arranged in a double row (the number of setae may differ in each row); tarsal claws symmetrical, simple, arolia present. Abdominal terga smooth, unspecialized. Supra-anal plate transverse, hind margin convexly rounded, entire with a group of small setae medially; paraprocts dissimilar, the right one hooklike apically (Figure 10C). Subgenital plate with a pair of widely separated, similar, slender, cylindrical styles (Figure 10D). Genitalia as in Figure 10D: hook on the right side, distal part darkly sclerotized, apical margin truncate without a preapical incision; median phallomere with a distinct setose L2d apically; left phallomere a large cleft. Colour: Head with pale occiput, the vertex black or dark brown, extending on the frons to the dark anteclypeus, the postclypeus, labrum (Figure 10A), and labial palps pale, maxillary palps dark; antennal flagellum pale, with a group of small setae medially; paraprocts similar, slender, cylindrical styles (Figure 10D). Abdominal terga with narrow raised mounds along the hind margins, these most pronounced medially, reduced or subobsolete laterally. Supra-anal plate convexly rounded, weakly indented medially, reaching the hind margin of the subgenital plate. Abdominal sterna with subobsolete elevations along the hind margins. Colour: Head and pronotum similar to male. Abdomen much darker; subgenital plate black.

Measurements (mm) (? in parentheses; N= 5 ♂, 5 ♀; averages in brackets)

Length, 22.0–22.5 [22.0] (20.0–24.0) [22.1]; pronotum length x width, 5.4–5.7 x 7.4–8.0 [5.6 x 7.8] (5.2–6.0 x 8.4–9.2) [5.6 x 8.7]; tegmen length, 19.6–22.0 [20.7] (5.2–6.4) [5.9]; interocular width, 1.4–1.5 [1.46] (1.9–2.1) [1.98]; interocellar width, 1.0–1.2 [1.04] (1.2–1.3) [1.22]; interantennal socket width, 1.7–2.0 [1.86] (1.9–2.1) [2.0].

Remarks

This species is closely related to M. perplexa (similarity in tegmina shape and pronotal pattern (cf. Figures), and looks very much like a small version of that species. Its genital phallomere L2d is similar to that of inquinata.

Dr David Rentz collected most of the specimens and supplied the following ecological information: “The Molytria were collected in a ‘Reserve’ consisting principally of large Spotted Gums, Eucalyptus maculata with an understorey of a variety of Persoonia, Acacia and Banksia species, with Pittospermum revolutum, and the Cycad Macrozamia communis. The cockroaches are found at night on the leaf litter or within 6 inches of the ground on stems. Early in the evening they have sand grains on their bodies suggesting they live in the soil during the day. I don’t know whether or not they construct burrows. They are most commonly seen on the ‘edge’ of this habitat where there is mowed grass over the sandy substrate. After dark they are seen on the grass, usually motionless.”

Etyymology

Refers to its small size when compared to the other two known species.

Genus Calolampra Saussure


Type Species

Calolampra irrorata (Fabricius) = Blatta irrorata Fabricius = Epilampra gracilis Brunner (Princis, 1963b: 147).

Remarks

Calolampra is an Australian taxon containing about 26 species. Most of them show strong sexual dimorphism.
dimorphism with the males being fully winged and the females having reduced tegmina and vestigial hind wings. The non-Australian species of “Calolampra” belong to other genera, namely: Calolamprades Bey-Bienko (Burma, India, Sri Lanka, Thailand), Howntinniella Roth (Philippine Islands), Juxtalolampra Roth (Burma, Thailand), Princisola Guney and Roth (Sarawak), and Pseudocalolampra Roth and Princis (Africa) (Roth, 1981: 405). Princis (1960: 438; 1963b: 147) placed the genus in the Laxtinae and McKittrick (1964) assigned it to the Epilamprinae. However, Grandcolas (1993) assigned it to the Diplopterinae (with Diploptera). I provisionally follow McKittrick and retain it in the Epilamprinae.

Calolampra elegans Roth and Princis

Calolampra elegans Roth and Princis, 1973: 103, figures 2–5 (♂ habitus); Roth, 1989: 50, figure 1A (♀ habitus); Roach and Rentz, 1998: 89.

Material Examined

Australia: Queensland: Emerald District, 1 ♂, 1 ♀, ex culture, gift of the Queensland Museum (MCZ).

Remarks

This is a large, distinctively coloured, wingless (both sexes) species. According to Dr G.B. Monteith (pers. comm., 25 July 1990), “Calolampra elegans has recently emerged as a minor pest of germinating legume crops in the Emerald region (near the type locality of Peak Downs) and apparently occurs in considerable numbers in ploughed fields. Quite a transition for something we thought of as a rarity!” The species is a herbivore and granivore and occurs in the soil and litter. It chews seedling stems of sunflower, sorghum, cotton, navy beans and maize (Roach and Rentz, 1998: 89).

Calolampra darlingtoni Roth and Princis

Calolampra darlingtoni Roth and Princis, 1973: 105, figures 6–13 (♂ and ♀); Roach and Rentz, 1998: 89.

Material Examined

Australia: New South Wales: The following were collected by C. and A.J. Jeekel: 5 km WNW. of Adaminaby [36°03'S, 148°43'E], st. 74, 2 ♂, 9.xi.1980; near Lake Glenbawn, 12 km ESE. of Scone [32°05'S, 150°51'E], st. 62, 1 ♀, 1.xi.1980; 5 km SW. of Bungendore [35°15'S, 149°26'E], 20 km ENE. of Queanbeyan [35°21'S, 149°14'E], st. 67, 1 ♀, 7.xi.1980 (ZMA).

Remarks

This is a volant, gregarious species that burrows under and inside rotting logs of Eucalyptus sp., Ceratopetalum sp., Syncarpia sp., and Casuarina sp., where they feed on decomposing wood. They live mostly in groups of a number of females, one male and different aged nymphs (Roach and Rentz, 1998: 108).

Panesthia servillei

Panesthia servillei: Roth, 1977: 1; 1979a: 3 (revision); Roach and Rentz, 1998: 105.

Remarks

There are about 54 species and nine subspecies of Panesthia that are found on the Asian mainland, Indonesian islands, and Australia. There are nine species and two subspecies in Australia. Since my revision, Asahina (1988: 60) added another subspecies of P. angustipennis, from Yayeyama Islands and Taiwan.

Panesthia cribrata Saussure


Material Examined

Australia: New South Wales: Harrington, 2 nymphs, 5.viii. 1965, G. Williams (PMYU). The following were collected by C. and A. Jeekel: Heaton State Forest, 22 km SE. of Cessnock, st. 64, 3 ♂, 2 ♀, 1 ♀ nymph, 2.xi.1980; Arding, 9 km NNE. of Uralla, st. 58, 1 ♂, 1 ♀ nymph, 31.x. 1980; 5 km E. of Tabulam, st. 54, 1 ♀ nymph, 29.x.1980 (ZMA); no exact locality: 4 ♂, 7 ♂ and 7 ♀ nymphs, Crampton; Dorrigo, 2 ♂, 1 ♀, Crampton (MCZ). Queensland: The following were collected by C. and A. Jeekel: Kondalilla Natn. Park, 11 km WSW. of Nambour, st. 4, 1 ♀, 30.ix.1980; Beerwah Natn. Forest, 7 km SSW. of Landsborough, st. 3, 1 nymph, 29.xi. 1980 (ZMA); no exact locality, rainforest, sea level, 1 ♀ nymph, 22.ix.1964, A. Cottrell (MCZ).

Remarks

This is a volant, gregarious species that burrows under and inside rotting logs of Eucalyptus sp., Ceratopetalum sp., Syncarpia sp., and Casuarina sp., where they feed on decomposing wood. They live mostly in groups of a number of females, one male and different aged nymphs (Roach and Rentz, 1998: 108).

Panesthia australis Brunner

Panesthia australis Brunner: Roth, 1977: 25, figures
Material Examined
Australia: New South Wales: 5 or 6 km SW. of Bungendore, 20 km NE. of Queanbeyan, 1 ♀ (with an ootheca in the brood sac), 5 nymphs, 7.xi.1980, C. and A. Jeekel; Kosciusko Nat. Park, Dead Horse Gap, 4 km SW. of Thredbo, 1600 m, 1 nymph, 6.iii.1989, P. Oosterbroek and C. Hartveld (ZMA); Brindabella Range, 3700 ft., dry sclerophyll for., 2 ♀, 1 ♀ nymph, 18.x.1964, A. Cottrell (MCZ).

Remarks
This is a gregarious species that lives in rotting wood (Roach and Rentz, 1998: 107).

Panesthia tryoni tegminifera Roth

Material Examined
Australia: New South Wales: Dorrigo, 1 ♀ nymph, Crampton (MCZ).

Remarks
A burrowing, gregarious species that lives in rotting wood (Roach and Rentz, 1998: 110).

Panesthia ancaudellioides Roth
Panesthia ancaudellioides Roth, 1977: 20, figures 12, 13 (♂ and ♀).

Material Examined

Remarks
The species is known only from around the Cairns district, Queensland. It is a burrowing, volant, gregarious species that lives in rotting wood.

Genus Parapanesthia Roth

Remarks
There are only two species in this Australian genus, namely P. gigantea and P. pearsoni Walker, Rugg and Rose.

Parapanesthia gigantea (Tepper)
Geoscaphicus gigantea Tepper, 1894: 176 (♂ lectotype only).
New cockroach species, mostly from Australia

**Polyzosteria limbata** Burmeister

*Polyzosteria limbata* Burmeister: Mackerras, 1965a: 852, figures 1, 3–14, pl. 2, figure 7 (habitus) (redescriptions: δ and Ψ); Roach and Rentz, 1998: 79.

Material Examined


Remarks

This is a large species found in Western Australia, South Australia, Victoria, New South Wales, and Tasmania. The species is a diurnal ground dweller and frequently climbs on shrubs to bask or forage. The oothecae are dropped or buried in sand (Roach and Rentz, 1998: 79).

**Polyzosteria viridissima** Shelford

*Polyzosteria viridissima* Shelford: Mackerras, 1965a: 870, figures 25, 36, pl. 1, figure 4 (habitus) (redescriptions: δ and Ψ).

Material Examined

Australia: New South Wales: The following were collected on the Australia/Harvard Expedition, on Mt. Kosciusko (type locality) in 1931: 5–7000 ft., 1 δ nymph, 10.xii., 3 δ, 4 Ψ, 1 δ and 1 Ψ nymphs, 11.xii., 5000 ft. 1 Ψ, 14.xii., 6000 ft., 1 δ, 2 Ψ, 1 Ψ nymph, 14.xii., P. Darlington, 4–5000 ft., 1 δ, 2 Ψ, 1 Ψ nymph, 15.xii., W.M. Wheeler (MCZ).

Remarks

This is a shiny, metallic green species known from the alpine areas of New South Wales and Australian Capital Territory. It is diurnal and has been taken on shrubs, tussock grasses and on or near sphagnum (Roach and Rentz, 1998: 81).

**Polyzosteria mitchelli** (Angas)


Material Examined


Remarks

This is a large, striking species easily recognized by its habitus (Shelford 1910: pl. 1, figure 2; Mackerras 1965a, pl. 1, figure 10). It is a ground dwelling, epigean species but has been taken in caves, and is widely distributed in Western Australia, South Australia, and New South Wales (Roach and Rentz, 1998: 80).

**Genus Celatoblatta** Johns


Remarks

Johns placed 13 New Zealand species in this genus. Princis (1971: 1147) transferred about a dozen Australian species in various genera to *Celatoblatta*.

**Celatoblatta sedilloti** (Bolivar)


**Genus Anamesia** Tepper

*Anamesia* Tepper, 1893: 69; Mackerras, 1966b: 335 (revision); Roach and Rentz, 1998: 41.

Remarks

There are 11 species in this Australian genus.

**Anamesia frenchii** Tepper

*Anamesia frenchii* Tepper, 1893: 72; Mackerras, 1966b: 347, figures 1, 13, 23, 33, pl. 1, figure 6 (habitus) (redescriptions: δ and Ψ); Roach and Rentz, 1998: 41.

Material Examined

Australia: Western Australia: Meekatharra, 2 δ, 1 Ψ, 3 δ nymphs, 25.ix.; Mullewa, 1 δ, 11.ix, P.J. Darlington on the Harvard/Aust. Exp. 1931 (MCZ).

Remarks

This diurnal species is found in Western Australia under logs, stones, or in clumps of spinifex (Roach and Rentz, 1998: 41).

**Genus Cosmozosteria** Stål


Remarks

There are 13 species of described *Cosmozosteria*, restricted to Australia.
Cosmozosteria bicolor (Saussure)


Material Examined
Australia: Queensland: The following were collected by C. and A. Jeekel: Clarke Creek, NW. of Rockhampton [23°23'S, 150°30'E], St. 31, 1 δ, 1 θ, 5 δ and 3 θ nymphs, 19.x.1980; 8 km E. of Gayndah [25°38'S, 151°36'E], St. 39, 1 θ nymph, 22.x.1980; Plainland [27°34'S, 152°25'E], 13 km E. of Gatton, St. 46, 1 δ nymph, 24.x.1980; 6 km S. of Alligator Creek, 24 km SE. of Townsville [19°15'S, 146°48'E], St. 25, 1 θ nymph, 14.x.1980; Dunk Island [17°57'S, 146°10'E], 1 δ, 16, 1896, A.G. Mayer. The following were collected by P. Darlington on various dates during the Australia/Harvard Expedition in 1932: Coen [13°56'S, 143°12'E], C. York, 1 θ, 4 δ and 2 θ nymphs; Mt. Carbine [16°32'S, 145°08'E], N. Qld., 2 δ, 1 δ nymph; Townsville, 2 δ, 1 θ (coll. Wheeler); Brisbane [26°20'S, 153°00'E], 1 δ, 1 δ and 1 θ nymphs (MCZ).

Remarks
The species is diurnal and is often found sunbasking on the ground, rocks and low foliage (Roach and Rentz, 1998: 43).

Genus Platyzosteria Brunner


Remarks
The are 90 species of Australian Platyzosteria: 31 belong to the subgenus Platyzosteria, 8 to the subgenus Leptozosteria, and 51 to the subgenus Melanozosteria (Roach and Rentz, 1998: 54, 63, 64).

Platyzosteria (Platyzosteria) novaeseelandiae (Brunner)


Material Examined
Australia: Queensland: The following were collected by C. and A. Jeekel, 22.x.1980: 4 km ESE. of Murgon [26°14'S, 151°57'E], St. 43, 1 δ (with ootheca); Cherbourg, 6 km S. of Murgon, St. 42, 1 δ; near Oakdene, 27 km ESE. of Gayndah [25°38'S, 151°36'E], St. 40, 1 θ (retained in MCZ) (ZMA).

Remarks
Two species of Platyzosteria occur in New Zealand. According to Johns, Platyzosteria novaeseelandiae is a very common species in the lowlands of North Island, and almost entirely coastal in the northern part of South Island.

Platyzosteria (Platyzosteria) melattaria (Erichson)


Material Examined
Australia: Victoria: Melbourne, 4 δ [one labelled Platyzosteria grandis (Sauss.) by Hebard, 1921]. New South Wales: Wentworth Falls [33°43'S, 150°23'E], 2800 ft., 1 δ, 1931, Darlington, Australia/ Harvard Expedition (MCZ). The following were collected by C. and A. Jeekel: 5 km SW. of Bungendore [35°15'S, 149°26'E], 20 km ENE. of Queanbeyan [35°21'S, 149°14'E], St. 67, 3 δ, 7.xi.1980; 20 km NNE. of Guyra [30°14'S, 151°40'], St. 57, 1 θ, 30.x.1980; Kosciusko Natn. Park, Rennex Gap, 12 km NW. of Jindabyne [36°25'S, 148°38'E], St. 71, 2 δ, 8.xi.1980 (ZMA); Cabramatta, under log, 1 δ, 31.vii.1965, M. I. Nikitin (PMYU). Tasmania: Ben Lomond Natn. Park, 35 km ENE. of Evandale [41°35'S, 147°14'E], St. 96, 1 δ, 3 θ (one carrying ootheca in vertical position), 1 δ and 3 θ nymphs, 23.xi.1980, C. and A. Jeekel (ZMA).

Remarks
According to Mackerras, this is a widely distributed species extending from southern Queensland, through New South Wales and Victoria to Tasmania, and into the southeastern part of South Australia. The species is diurnal and is found under bark and in litter. The oothecae are dropped on the ground or buried in sand or moss. The species apparently does not discharge a defensive secretion (Roach mid Rentz, 1998: 59) which is surprising since species of Platyzosteria are known to have repugnatorial glands used when disturbed (Roach and Rentz, 1998: 59).

Platyzosteria (Platyzosteria) anceps Shaw


Material Examined
Australia: Queensland: The following were collected by C. and A. Jeekel, 22.x.1980: 4 km ESE. of Murgon [26°14'S, 151°57'E], St. 43, 1 θ (with ootheca); Cherbourg, 6 km S. of Murgon, St. 42, 1 δ; near Oakdene, 27 km ESE. of Gayndah [25°38'S, 151°36'E], St. 40, 1 θ (retained in MCZ) (ZMA).
New cockroach species, mostly from Australia

Remarks
The species has been reported only from Queensland, and is found under bark.

**Platyzosteria (Platyzosteria) scabrella Tepper**


Material Examined

Remarks
This very variable species is found in the southeastern corner of Queensland, eastern New South Wales, Australian Capital Territory, Victoria, and the southeastern part of South Australia. It is found under bark, rocks, logs and litter (Roach and Rentz, 1998: 61).

**Platyzosteria (Platyzosteria) scabra Brunner**


Material Examined
Australia: New South Wales: no exact locality, 1 δ, 2 Ψ, Crampton (MCZ).

Remarks
The species is found in the southeastern corner of Queensland, and the eastern coast of New South Wales where it can be collected under bark and stones (Roach and Rentz, 1998: 60).

**Platyzosteria (Melanozosteria) soror (Brunner)**


Material Examined
Amboina: Moluccas: Ambon, 1 Ψ, Toxopeus (ZMA). British Solomon Islands: The following were collected by M.J.A. de Koster: Eiland Florida (= Small Gela = Nggela), rond dorp Belaga, 5 δ, 2 Ψ, 2 δ and 1 Ψ nymphs, 1963/1964, 1 Ψ, 12-31.xii.1963, 3 δ and 1 Ψ nymphs, 1966, 7 δ, 2 Ψ, 1 Ψ nymph, 1967; Small Gela (=Florida Island), 8 δ, 8 Ψ, 1 δ nymph; (ZMA). Two pairs retained in (MCZ). Austral Island (Polynesia): Rapa, Pukutaketake, 100–200 m, open field, 1 Ψ, 6.ii.1980, Gustav Paulay (PMYU). United States: Hawaii: The following are all from Oahu: 1 δ, 1864, H. Mann; Moluleia Beach, 1 δ, Kolekola Pass, 1 δ, 1 Ψ, W.M. Wheeler; Oahu and Kauai, 4 δ, 1 Ψ, Expl. Exp., C. Pickering (S.H. Scudder coll.); N. ridge, Mt. Konahuanui, 1500–2000 ft., 1 δ, Levy, Werner, Parsons; ridge above Kuluiouau Valley, Koolau Rge., 800–1200 ft., 1 Ψ, 29.i.1945, Werner; Manoa, 1 Ψ, v.1906, F.Y. Oshiro (MCZ).

Remarks
This is a very widely distributed and common species. According to Mackerras, it is not found in Australia but is common to the Islands north of that continent. The type is from Amboina.

**Platyzosteria (Melanozosteria) secunda (Tepper)**

*Platyzosteria* (Melano.) *secunda* (Tepper): Mackerras, 1968a: 249, figures 14, 26, 35, 45, 50, pl. 2, figures E, F (habitus) (redescriptions: δ and Ψ); Roach and Rentz, 1998: 76.

Material Examined

Remarks
There is a question about the valid specific name of this taxon. Princis (1966: 577) lists secunda as a synonym of *Melanozosteria triangulata* Brunner. However, Mackerras (1968: 251) claimed that triangulata is a nomen nudum. Roach and Rentz (1998: 75) lists the species as *Platyzosteria (Melanozosteria) triangulata* (Brunner).

**Platyzosteria (Melanozosteria) bicolor Kirby**


Material Examined
Australia: Queensland: Rocky Scrub, McIlwraith Rge. [13°43'S, 143°23'E], Cape York, 2 Ψ, vi.1932, Darlington, Australia/ Harvard Exp. (MCZ).

Remarks
The types are from Dauan Island [9°25'S, 142°32'E] (as Cornwallis Island); the species also occurs in northern Queensland, and according to Shaw (1925: 179) in New Guinea. It is found under bark.
**Platyzosteria** *(Melanozosteria)* nitida (Brunner)


**Material Examined**
Samoa: Apia, 2 ♂, 4 ♀, Crampton (MCZ).

**Remarks**
This is a widely distributed species reported from Taiwan, Philippines, Malaya, Moluccas, Santa Cruz I., Hollandia, New Hebrides, Solomon Islands, Louisiade Archipelago, New Ireland, New Zealand, southeastern Papua New Guinea, the eastern coast of Queensland, and islands off the eastern coast of that state. It is found under bark.

**Platyzosteria** *(Melanozosteria)* illingworthi (Shaw)


**Material Examined**
Moluccas: Burn: Station 1 ♂, 2-6.xii.1921, L. J. Toxopeus (ZMA).

**Remarks**
This species is unusual in having “tegmina” that are only indicated by a curved groove that does not reach the pronotal and metanotal margins; the male has an asymmetrical subgenital plate with the left style longer than the right one, and a single curved spinelike process medially on the interstylar margin. One other species, *P. uncinata* (Shaw), shares these characteristics, but its thorax and abdominal terga have yellow markings whereas *illingworthi* is reddish brown (Mackerras, 1968a: 254). *Platyzosteria* illingworthi has been reported from northern Queensland, Moa Island (Torres Straits), and Northern Territory. The present record appears to be the first for the Moluccas. The species is found under bark.

**Platyzosteria** *(Melanozosteria)* castanea Brunner


**Material Examined**
Australia: New South Wales: 20 km NNE. of Guyra [30°14'S, 151°40'E], St. 57, 1 ♂, 2 ♀, 30.x.1980, C. and A. Jeckel (ZMA). Victoria: Melbourne [37°50'S, 145°00'E], 2 ♂ (one labelled *Platyzosteria biglumis* (Sauss.), by Hebard, 1921) (MCZ).

**Remarks**
The species also is known from the Australian Capital Territory. It is found under bark and has been recorded from a granite outcrop (Roach and Rentz, 1998: 67).

**Genus Zonioploca** Stål

*Zonioploca* Stål: Mackerras, 1965c: 903 (revision); Roach and Rentz, 1998: 82.

**Remarks**
There are nine known species of *Zonioploca* recorded only from Australia.

*Zonioploca pallida* Shelford

*Zonioploca pallida* Shelford: Mackerras, 1965c: 911, figures 5, 14, 23, pl. 1, figures 5, 6 (habitus) (redescriptions: ♂ and ♀); Roach and Rentz, 1998: 84.

**Material Examined**
Australia: Western Australia: Shannon Riv. [34°52'S, 116°24'E], Mill S. of Manjimup, savannah for., 1 ♂, 23.xi.1964, A. Cottrell (MCZ).
New cockroach species, mostly from Australia

Remarks
According to Mackerras, this species appears to be restricted to the south-western corner of Western Australia. It is a ground dweller.

Zonioploca medilinea (Tepper)

Zonioploca medilinea (Tepper): Shelford, 1910: 8, pl. 1, figure 4 (habitus); Mackerras, 1965c: 914, figures 8, 17, 28, pl. 1, figure 9 (habitus) (redescriptions: δ and Ψ); Roach and Rentz, 1998: 83.

Material Examined
Australia: Western Australia: Chariton Find, 1000 ft., sand plain, 1 δ, 11.xi.1964, A. Cottrell (MCZ).

Remarks
This is an epigean, ground dwelling species but has been taken in a cave. It has also been recorded from South Australia and Victoria (Roach and Rentz, 1998: 84). It is easily recognized by the dark median line on the meso-, metanotum, and abdominal terga.

Zonioploca occidentalis Mackerras

Zonioploca occidentalis Mackerras, 1965c: 908, figures 3, 12, 21, pl. 1, figure 3 (habitus) (redescriptions: δ and Ψ); Roach and Rentz, 1998: 84.

Material Examined
Australia: Western Australia: 18 miles E. of Bonnie Rock, Lake Varley (32°46'S, 119°27'E), 1000 ft., sand plain, 1 δ, 8–12. xi.1964, A. Cottrell (MCZ).

Remarks
This is a ground dweller known only from Western Australia.

Genus Temnelytra Tepper

Temnelytra Tepper: Mackerras, 1968b: 534 (revision); Roach and Rentz, 1998: 40.

Remarks
Only four species of Temnelytra are found in Australia.

Temnelytra truncata (Brunner)


Material Examined
Australia: Victoria: Melbourne [37°50'S, 145°00'E], 3 δ, H. Edwards (MCZ).

Remarks
The species is also known from New South Wales, South Australia, and Tasmania.

Genus Scabina Shelford


Remarks
There are two species in this genus, one from Australia, and the other, S. horrida Hanitsch, from Sumatra and Borneo.

Scabina antipoda (Kirby)


Material Examined

Remarks
The species is known from coastal northern New South Wales and southern Queensland. It is found under bark in rainforest. The oothecae are glued to undersides of bark and the nymphs require humid conditions (Roach and Rentz, 1998: 40).

Genus Methana Stål


Remarks
There are ten species of Methana in Australia (Mackerras, 1968b; key p. 518) and one in New Guinea (Princis 1966: 601).

Methana soror (Saussure)


Material Examined

Remarks
A distinctive species with a pair of pale maculae on the dark pronotal disk. Previously known only from Macleay River (30°52'S, 153°01'E), New South Wales. It is found under bark.
Methana marginalis (Saussure)

*Methana marginalis* (Saussure): Mackerras, 1968b: 519, figures 1, 2a–c, 11, 12, 17, 18, 70 (habitus), 100, 101 (redescriptions: δ and Θ); Roach and Rentz, 1998: 38.

**Material Examined**

**Australia: Queensland:** Brisbane [27°30'S, 153°01'E], 1 ♀ (carrying fully formed ootheca), 27.ix.1992, D. Furth (MCZ).

**Remarks**

This species is fairly common in coastal areas of Queensland (Mackerras 1968b: 521). It is found under bark of dead trees and in foliage of living trees. Females attach their oothecae to the undersides of loose bark and leaves and cover them with debris (Roach and Rentz, 1998: 38).

|Methana convexa (Walker)|
---|---|

**Material Examined**


**Remarks**

The species is found in Queensland and New South Wales, under bark. The female fastens the ootheca to bark and covers it with debris. Both nymphs and adults produce a strong defensive secretion (Roach and Rentz, 1998: 37).

**Genus Drymaplaneta Tepper**

*Drymaplaneta* Tepper: Mackerras, 1968b: 543 (revision); Roach and Rentz, 1998: 34.

**Remarks**

There are six species of *Drymaplaneta* in Australia. Princis (1966: 569) treated this genus as a synonym of *Melanozosteria*, but Mackerras, and Roach and Rentz considered them distinct taxa.

|Drymaplaneta semivitta (Walker)|
---|---|

**Material Examined**

**Australia: Western Australia:** Perth [31°58'S, 115°50'E], 1 ♀, 5 ♀, 1 ♀, 1 ♀, 1 ♀, i., W.S. Brooks; Margaret River, S.W.A., 2 ♀, 2 ♀, 30.x., P. J. Darlington, Harvard Aust. Exped. [1932] (MCZ).

**Remarks**

According to Mackerras, this species appears to be restricted to the southwestern part of Western Australia and apparently is a common domestic pest in various settlements and throughout Perth. The third and fourth maxillary palpi are greatly enlarged and distinctive.

**Drymaplaneta heydeniana (Saussure)**

*Drymaplaneta heydeniana* Saussure, 1864: Mackerras, 1968b: 549, figures 38a–d, 46, 87 (habitus) (redescriptions: δ and Θ); Roach and Rentz, 1998: 35.

**Material Examined**

**Australia: Western Australia:** Pemberton [34°28'S, 116°01'E], 1 ♀, 10.xi., P.J. Darlington, Harvard Australia Exped. [1932] (MCZ).

**Remarks**

The male's third and fourth maxillary palpi are only slightly enlarged and the hind tibiae are not specialised in this species which apparently is restricted to coastal southwest and northwest Western Australia. It occurs under bark (Roach and Rentz, 1998: 35).

**ACKNOWLEDGEMENTS**

I thank the curators and museums listed in the introduction for lending me the specimens. Most of the work was done when I had partial support from the Australian Biological Resources Study (ABRS), and I am grateful to them.

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L.M. Roth
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Cover: Zenobiathyris mutabilis – a new species of Late Cretaceous brachiopod described from the Carnarvon Basin.
Illustration by Jill Ruse.
Feia nota, a new species of gobiid fish from Western Australia

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Abstract - Feia nota is described from the 17.7 mm SL holotype from Bessieres Island, Western Australia. It is distinguished from F. nympha, the only other described species of the genus, in having 16 pectoral-fin rays, no pelvic fraenum, mostly ctenoid scales, 26-27 scales in lateral series, and a distinctive coloration (head and body generally dark with series of pale spots on dorsal midline; pectoral fin hyaline; caudal fin brown with dark basal bar).

INTRODUCTION

Smith (1959) erected the genus Feia to accommodate his new species F. nympha from Pinda, Mozambique. Lachner and McKinney (1979) redescribed the species based on a reexamination of the holotype and on additional specimens from the Seychelles, Indonesia and the Great Barrier Reef. They also reported on two specimens of a possibly undescribed species of the genus from Rapa Island, Austral Islands, but elected to not describe it.

In May 1996, the present authors and J.B. Hutchins surveyed shorefishes from the West Pilbara Islands, Western Australia. Among the fishes collected was a single specimen of a Feia species, described herein as new.

MATERIALS AND METHODS

Measurements to the snout tip were made to the midanterior tip of the upper jaw: standard length (SL) from the snout tip to the midposterior part of the hypural plate; head length from the snout tip to the posterior (vertical), fleshy edge of the operculum; and preanal, predorsal and prepelvic lengths from the snout tip to the anterior edge of the first spine base of the relevant fin. Head width was measured between the posterior edges of the preopercle, and head depth at the vertical through the preopercle. Eye diameter was measured horizontally where greatest. Bony interorbital width was the least width. Distance between the first and second dorsal-fin origins was measured between the anterior edges of the first spine base of each fin. Caudal peduncle depth was measured between the bases of the last segmented rays in the anal and the second-dorsal fins. Caudal peduncle length was measured from the posterior edge of the base of the last anal-fin ray to the ventral edge of the caudal peduncle at the vertical through the posterior edge of the hypural plate. Fin ray lengths were measured from the bases of the rays to their tips. Caudal fin length was the length of the lowermost ray articulating with the upper hypural plate (i.e., hypurals 3 + 4). Pectoral fin length was the length of the longest ray. Pelvic fin length was measured from the base of the spine to the distal tip of the fourth segmented ray.

The last segmented ray in the anal and second-dorsal fins is divided at its base and was counted as a single ray. Lateral scale series were counted along the midside from the pectoral-fin axil to the midbase of the caudal fin. Transverse scale series were counted upward and forward from the anal-fin origin.

Osteological details were determined from an x-radiograph. The pattern of interdigitation of first dorsal-fin pterygiophores with neural spines is given as a first dorsal pterygiophore formula following the methods of Birdsong et al. (1988). Comparisons with other Feia species are based on data provided by Lachner and McKinney (1979) and the following specimens (institutional codes follow Leviton et al., 1985): Comoros, ROM 56576 (1: 13.6 mm SL), ROM 56577 (1: 11.1 mm SL); Chagos, ROM 55113 (11.1 mm SL), ROM 55114 (2: 12.1-12.4 mm SL); Naira Islands, Banda Sea, USNM 216426 (1: 13.2 mm SL); Papua New Guinea, USNM 220107 (1: 14.8 mm SL), USNM 220108 (1: 13.2 mm SL); Tonga, USNM 339821 (1: 16.4 mm SL), USNM 339883 (5: 12.6-14.5 mm SL), USNM 340067 (5: 11.9-14.8 mm SL); Moorea, ROM 60711 (3: 13.2-14.8 mm SL); Rapa Iti, BPBM 17255 (1: 15.8 mm SL), BPBM 17300 (1: 15.2 mm SL).
SYSTEMATICS

Family Gobiidae Cuvier, 1829

Genus Feia Smith, 1959

Feia nota sp. nov.

Figures 1, 2, 3A

Holotype

WAM P.31440-001, 17.7 mm SL male, Western Australia, Bessieres Island, 21°45'02"S, 114°45'13"E, 1.5–2 m deep gutter in coral-rock reef with rock, coral rubble and sandy silt bottom and small caves in sides of gutter, 13–15 m, rotenone, R.D. Mooi, A.C. Gill, R.C. Miles and N. Williams, 15 May 1996 (field number RDM 96-23).

Diagnosis

A species of Feia (see Remarks below) with the following characters: pectoral-fin rays 16; no pelvic fraenum; scales mostly ctenoid, extending anteriorly to pectoral-fin axil; scales in lateral series 26–27; tongue slightly bilobed; anterior row of preopercular neuromasts positioned relatively close to preopercular margin; gill opening extending anteriorly to vertical through about midway between posterior margins of preopercle and operculum; medial epaxial muscle fibres extending forward beyond lateral muscle fibres to vertical through pupil, the anterior margin of epaxial musculature convex; head depth 19.8% SL; orbit diameter 7.3% SL; bony interorbital width 5.1% SL; head and body generally dark with series of pale spots on dorsal midline; pectoral fin hyaline; and caudal fin brown with dark basal bar.

Description

Dorsal-fin rays VI + 1,9, all segmented rays branched; anal-fin rays 1,9, all segmented rays branched; pectoral-fin rays 16/16, all rays branched; pelvic-fin rays 1,5, all segmented rays branched; segmented caudal-fin rays 9 + 8; branched caudal-fin rays 7 + 6; upper unsegmented caudal-fin rays 6; lower unsegmented caudal-fin rays 6.

Figure 1 Feia nota, WAM P.31440-001, 17.7 mm SL male holotype, Bessieres Island, Western Australia, A, dorsal view; B, right lateral view. (Photographs by P. Crabb.)
A new gobiid fish from Western Australia

Head, nape, prepelvic area and narrow area of body immediately below dorsal fins naked; scales on body and caudal peduncle mostly large and ctenoid, becoming smaller, less regularly arranged and cycloid on belly, immediately adjacent to anal-fin base, and on dorsal part of body (approximately above oblique line passing from pectoral-fin axil to base of last second-dorsal-fin ray); lateral scale series 26/27; transverse scale series 13/12.

Cephalic sensory pores absent; pattern of superficial neuromasts on head as shown in Figure 2.

Gill rakers relatively long and slender, \(3 + 10\); gill opening extending anteriorly to vertical through about midway between posterior margins of preopercle and operculum (Figure 2C); pseudobranch filaments 5; tongue slightly bilobed, the tip free; medial epaxial muscles extending forward beyond lateral muscles to vertical through pupil, the anterior margin of epaxial musculature convex (Figure 3A).

Pelvic-fin rays reaching slightly beyond anus; fifth segmented pelvic-fin rays broadly united basally by fin membrane, pelvic fraenum absent (Figure 2C).

Each premaxilla with outer row of about 6 or 7 caninoid teeth, the lateralmost few teeth enlarged and recurved, followed by 1 or 2 rows of small villiform teeth, and innermost row of slightly enlarged (about equal to medial teeth of outer row), depressed, caninoid teeth; each dentary with outer row of 4–6 caninoid teeth, the lateralmost 1 or 2 teeth strongly enlarged and recurved, followed by 1 or 2 rows of small villiform across front of dentary, and innermost row of slightly enlarged (about equal to medial teeth in outer row), depressed, caninoid teeth, the innermost row of teeth extending posteriorly on to sides of jaw; vomer, palatine and tongue edentate.

Vertebrae 10 + 16; first dorsal pterygiophore formula 3-22110; anal pterygiophores in front of first haemal spine 2; pu2 neural and haemal spines somewhat spatulate.

As percentages of SL: head length 32.3; orbit diameter 7.3; head width 20.9; bony interorbital

Figure 2  *Feia nata*, holotype, WAM P.31440-001, showing distribution of superficial neuromasts on the head in A, dorsal; B, lateral; and C, ventral view. Arrow and stippling in C indicate, respectively, anterior extent of right gill opening, and basal membrane connecting fifth segmented pelvic-fin rays. Scale bar = 2 mm.
width 5.1; head depth 19.8; body depth at pelvic origin 20.3; body depth at anal-fin origin 18.6; predorsal length 39.5; prepelvic length 30.5; preanal length 58.8; first-dorsal-fin origin to second-dorsal-fin origin 20.9; caudal peduncle depth 13.6; caudal peduncle length 22.6; length of second dorsal-fin base 19.8; length of anal-fin base 18.1; length of third spine in first dorsal fin 14.1; length of third last segmented ray in second dorsal fin 16.4; length of third last segmented anal-fin ray 18.6; pelvic fin length 26.0; pectoral fin length 23.7; caudal fin length 28.2.

Live coloration (based on colour photographs of holotype when freshly dead; see Mooi, 1996): head and body pale brown with dense covering of melanophores and brown chromatophores; melanophores and brown chromatophores largest on head, aligning to form three dark bars; first bar narrow, extending ventrally from anteroventral part of orbital rim to just behind corner of mouth; second bar broad, extending from posteroventral part of orbital rim to ventral (anterior) part of preopercle; third bar broad, extending vertically from anterior part of nape through posterior edge of preopercle; iris reddish brown; scales dark brown on edges, giving reticulate pattern; dorsal part of head and body with series of eight pale cream to white spots; first spot above posterior edge of opercle; second spot above vertical through pectoral-fin base; third spot between bases of third to fifth dorsal-fin spine, encroaching slightly on to first-dorsal-fin base; fourth spot between posterior part of first dorsal fin and base of first segmented ray of second dorsal fin, encroaching well on to basal part of both fins; fifth spot between bases of third and fifth segmented rays of second dorsal fin, encroaching well on to basal part of fin; sixth spot indistinct, between bases of seventh and ninth segmented rays of second dorsal fin and encroaching well on to basal part of fin; seventh spot indistinct, just behind termination of second dorsal fin; eighth spot on posterior part of caudal peduncle; second, intermittent series of indistinct pale brown spots immediately beneath dorsal series of spots, these aligned between dorsal spots to give indistinct reticulate pattern; first dorsal fin brown basally (excepting pale spots; see above), with dense scattering of brown chromatophores, the distal third of fin pale cream to white; second dorsal fin with dense scattering of brown chromatophores, the base of fin brown (excepting pale spots; see above) and distal third to half of fin pale yellowish brown; anal fin brown, becoming yellowish brown distally, with dense scattering of brown to red chromatophores; caudal fin with dark greyish
brown basal bar, the remainder of fin brown with dense scattering of brown to red chromatophores; pectoral fins hyaline; pelvic fins hyaline, with red to brown melanophores along pelvic-fin spine and on basal part of segmented rays.

Preserved coloration: similar to live coloration, except paler.

**Comparisons**

*Feia nota* differs from congeneric specimens described by Lachner and McKinney (1979) and examined by us (see Materials and Methods) in the following: pectoral-fin rays 16 (versus 14-15); pelvic fin fraenum absent (versus weakly to moderately developed fraenum present or absent); scales mostly ctenoid (versus entirely cycloid), extending anteriorly to pectoral-fin axil (versus not extending anteriorly beyond vertical through origin of second dorsal fin); scales in lateral series 26-27 (versus 14-25); tongue slightly bilobed (versus rounded to truncate); anterior (termed “outer” by Lachner and McKinney, 1979) row of preopercular neuromasts positioned relatively close to preopercular margin (versus well in advance of preopercular margin); gill opening extending anteriorly to vertical through midpoint between posterior margins of preopercle and operculum (versus to slightly below and in front of pectoral-fin insertion); medial epaxial muscle fibres extending forward beyond lateral fibres to vertical through pupil, the anterior margin of epaxial musculature convex (versus medial epaxial muscle fibres extending to vicinity of posterior edge of eye, with lateral epaxial fibres extending further forward, resulting in concave anterior margin to epaxial musculature; cf. Figures 3A, B); head depth 19.8% SL (versus 13.5-18.5% SL); orbit diameter 7.3% SL (versus 5.0-6.2% SL); and bony interorbital width 5.1% SL (versus 2.5-4.0% SL). Moreover, it differs markedly from congener specimens necessitates the following slight modification of the diagnosis provided by Lachner and McKinney (1979: 11) for *Feia*: head barbels absent; two short rows of superficial neuromasts on chin arranged in V-shaped pattern; at least some superficial neuromasts on head and body borne on elongate, flap-like papillae; superficial neuromasts arranged in short regular columns on body; fleshy cheek fold absent; cephalic sensory pores absent; second dorsal-fin rays 1,7-9; anal-fin rays 1,8-9; pectoral-fin rays 14-16; at least head, nape and dorsal area of body naked; and sickle-shaped dark mark at base of pectoral fin absent.

**Etymology**

The specific epithet is from the Latin for ‘mark’ and alludes to the pale spots on the dorsal part of the body. Gender is feminine.

**ACKNOWLEDGEMENTS**

We are grateful to J.B. Hutchins for participating in and helping to organise the fieldtrip to the West Pilbara Islands, and to the crew of the *Lionfish III* (S. Jones, N. Williams and R. Miles) for collecting assistance and making sure everything ran smoothly on board. We thank J.E. Randall, A. Suzumoto, J. Williams and R. Winterbottom for loaning *Feia* specimens; R. Winterbottom also lent a colour photograph of a specimen from Moorea. An x-radiograph and photographs of the holotype of *F. nota* were provided by S. Davidson and P. Crabb, respectively. We thank D.F. Hoese for helpful discussions. H.K. Larson and H. Gill reviewed the manuscript and provided useful comments. This publication is based, in part, upon work supported by the National Science Foundation (U.S.A.) under Grant No. DEB-9317695 to RDM.

**REFERENCES**


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Gondwanodus irwinensis gen. et sp. nov., a new elasmobranch from the Early Permian (Late Sakmarian) Fossil Cliff Member of the Holmwood Shale, Perth Basin, Western Australia

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Abstract - A new elasmobranch is described from the Early Permian (Sakmarian, Sterlitamakian) of Western Australia. Gondwanodus irwinensis gen. et sp. nov. is represented by a single tooth which has a lingually prominent rectangular coronal base, a long, wide, robust tooth root and a low, medially acuminate crown. The tooth shares the lingually prominent coronal base with the petalodonts and Heteropetalus. The morphology of the tooth suggests a specialized durophagous diet that may have included small decapod crustaceans or phyllocarids. The specimen was recovered from residue obtained through acid etching of small limestone blocks collected from Fossil Cliff in the northern part of the Perth Basin. The sediments are glacio-marine in origin and were formed when the Perth Basin was located at a latitude of approximately 70°S. To date a vertebrate fauna comprising symmoriid and stethacanthid shark teeth, a variety of placoid scales, and teeth and scales of palaeoniscoid fish, has been recovered.

INTRODUCTION

Australian Permian vertebrate microremains are generally rare (Turner, 1991) and the Permian fish fauna of Australia is poorly known. This is particularly true for Western Australia where the only described fauna has been Crassidonta subcrenulata Teichert, 1943, Helodus sp. Teichert, 1943, Helicoprion davisii H. Woodward, 1886 (rec: Woodward, 1886; Teichert, 1940, 1943), all from the Wandgee Series of the Carnarvon Basin, and a cryphiolepidid, gen. et sp. indet. Archbold, 1981 from the Byro Group, also in the Carnarvon Basin (Long and Turner, 1984). Fossil vertebrate remains from the Fossil Cliff Member of the Holmwood Shale at Fossil Cliff have previously been reported by the author (Daymond, 1993). Numerous palaeoniscoid teeth and scales, and rarer shark teeth were recovered from the limestone by Ferdinando (1992). Further work by the author on small limestone blocks collected from the type section at Fossil Cliff has revealed a new elasmobranch tooth along with several teeth of symmoriid and stethacanthid sharks, some placoid scales, and teeth and scales of palaeoniscoid fish. The fauna shows similarities with that of the Upper Pennsylvanian Shawnee Group, Kansas, as illustrated in Tway and Zidek (1982: figures 27A–E, 38A–E, 60A–E, 1983 figures 1A, B, 2A, B, 5A, B, 7A, B, 18A, B). Until the discovery of the large stethacanthid specimens described by Daymond (1993), in the sandy shale facies of the Fossil Cliff Member, all Permian fish records from Western Australia were from marine limestones (Turner, 1993). It is proposed that future collection and study of microvertebrate specimens from this locality will increase our knowledge of the Permian marine vertebrate fauna from this part of the world.

LOCALITY INFORMATION

Fossil site

Fossil Cliff (lat. 28°56′35″S, long. 115°32′30″E) is situated on the north branch of the Irwin River (Mingenew District) in the northern part of the Perth Basin (Irwin Sub-basin), 400 kilometres NNE of Perth, Western Australia (Figure 1).

Approximately 2600 metres of Permian sediments are contained within the Irwin Sub-basin (Playford, et al. 1976). The Holmwood Shale consists of 450 metres of micaceous and jarositic shale, siltstone, and discontinuous coquinitic limestone. It conformably overlies the glacial Nangetty Formation, which is the lower-most Permian formation in the sub-basin, and is conformably overlain by the near-shore marine sediments of the High Cliff Sandstone. The Fossil Cliff member is the uppermost unit of the Holmwood Shale. The type section of the Fossil Cliff Member outcrops on the west bank of the river, which is normally dry and flows only after heavy rain, consists of sandy siltstones, shales and mudstones with lenticles of indurated grey to yellow limestone. It contains a rich invertebrate fauna of brachiopods, pelecypods,

**Stratigraphic occurrence**

The type, and only specimen, comes from a grey indurated silty limestone facies, massive to weakly bedded, occurring between 8.5 to 9.5 metres above the base of the Fossil Cliff Member of the Holmwood Shale (Figure 2). It was recovered from a 5 cm band that is particularly rich in small fragments of brachiopods, bryozoans and crinoids. This bed occurs as small, irregular lenses within the limestone suggesting that the deposit was the result of a gentle winnowing current on the sea-bed (Ferdinando, pers. comm.).

**MATERIALS AND METHODS**

Acetic acid etching of the limestone blocks was carried out following methods described by Rixon (1976). Whitelaw and Kool (1993) reported that during acid preparation, matrices with a high clay content posed difficulties as the clay quickly forms a skin over the rock surface and acts as a buffer, limiting the effect of the acid and necessitating frequent rinsing. Because of the high clay content of the Fossil Cliff matrix, a relatively high concentration of 15% glacial acetic acid at an initial temperature of 40°C was found to allow maximum disaggregation before the formation of a skin with no detrimental effects on the microvertebrate specimens. The residue was washed in a 180 μm aperture mesh seive, dried, then sorted under a binocular dissecting microscope. Vertebrate remains in the limestone are rare with a specimen being recovered every 4 or 5 inspections. The quality of preservation is excellent with even the most delicate structures intact. Previous specimen recovery by Ferdinando was done by initial mechanical disaggregation and then boiling of the matrix (Ferdinando pers. comm. 1998) which showed a collecting bias toward the survival of the generally more robust palaeoniscoid specimens. The quantities of chondrichthyan and palaeoniscoid specimens so far recovered by the author are nearly equal. This reflects the gentler method of acid preparation which ensures the survival of the more delicate shark remains.

The SEM photographs were made using a Phillips 505 Scanning Electron Microscope. The specimen is lodged in the collections of the Western Australian Museum (WAM).

**ENVIRONMENT OF DEPOSITION**

Recent palaeomagnetic studies have shown that during the early Permian, the Perth basin was situated in eastern Gondwana at a latitude of approximately 70°S (Li, Z.-X., et al. 1993). Work in the area by D. Ferdinando (pers. comm. 1995) has supported the hypothesis that the Irwin Sub-basin sediments were deposited in a barred basin (Clarke, et al. 1951). A model proposed by Le Blanc Smith and Mory (1995) suggests that the Holmwood Shale is glaciomarine in origin, with the sediments being deposited by glacial meltwaters into a large standing waterbody created by the retreat of the continental ice sheet as the climate warmed. The presence of recognised cold-water pelecypods such as *Deltopecten* and *Lyonia* is evidence of a cold water temperature (Dickens, 1993). The impoverished invertebrate fauna in the lowermost strata of the Holmwood Formation suggests that the water was probably initially brackish and then marine. The envisioned embayment had an ocean connection to the north (Le Blanc Smith and Mory, 1995).

During deposition of the Holmwood Shale sediments the water was relatively shallow; the sea-bed having only a very slight gradient so that water depth was rather uniform over the entire basin (Ferdinando, pers. comm. 1995). The presence of appreciable amounts of gypsum, jarosite and
Gondwanodus gen. nov.

Type Species
Gondwanodus irwinensis, sp. nov.

Diagnosis
An elasmobranch tooth that is microscopic (2 mm wide measured across the base), robust and low-crowned. Crown base is rectangular and labiolingually elongate with thick, smooth, rounded margins. The coronal basal margin is lingually prominent. Crown down curved labiolingually and has a single, short acuminate cusp lacking surface ornamentation. The tooth root is deep, wide, flared, hexagonal and robust with lower half lingually prominent. The tooth root is twice as long as the crown is high. Shallow nutritive foramina occur on both the lingual and labial surfaces of the tooth root.

Etymology
Named after the Gondwana landmass to which Australia belonged during the Permian period.

SYSTEMATIC PALAEONTOLOGY

Class Chondrichthyes Huxley, 1880
Subclass Elasmobranchii Bonaparte, 1838
Order incertae sedis
Family incertae sedis

Mottled sandstone.

White sandy shale.


Grey calcarenite. Massive.

Brown semi-indurated calciltite to calcarenite. Massive.

Brown calcarous siltstone. Weakly bedded.

Grey to black shale. Finely laminated.

Grey calciltite to calcarenite. Highly indurated. Lensoidal.

Figure 2 Stratigraphic section of the type locality, Fossil Cliff member, Holmwood Shale Formation (after Ferdinando).
Cliff, Western Australia, Australia.

Holotype and Only Specimen
WAM 98.7.1. single complete tooth from Fossil Cliff, Western Australia, Australia.

Diagnosis
As for genus.

Description
The crown is down-curved labioliogually with the prominent, rounded lingual margin of the coronal base overhanging the tooth root by one third of the coronal labioliogual length (Figures 3C, E, 4C). The rounded labial margin of the coronal base protrudes only slightly over the line of the tooth root (Figures 3B, 4C). The low cusp extends vertically from the centre of the coronal base (Figures 4A, C). The lateral surfaces of the cusp are initially perpendicular to the crown then rapidly converge to form an apex (Figures 3F, 4A, B). The labial and lingual surfaces are gently curved to the apex of the cusp (Figure 4C). No surface ornamentation is visible on the crown or cusp (Figure 3D). Dorsally the lingual coronal surface is flat with two shallow depressions, separated by a narrow ridge, located lingual to the cusp (Figures 3E, 4B, D). The labial coronal surface is concave; the concavity narrowing and deepening from the cusp to the labial margin (Figure 4D).

The tooth root is wide with the lateral margins flaring from underneath the crown to approximately two-thirds of the tooth root length and then converging to a truncated bottom margin forming a hexagonal shape (Figures 3A, E, 4A, B). The length of the tooth root is twice the height of the crown. The lingual basal surface exhibits small nutritive foramina on each side extending from under the crown to the points where the lateral margins converge toward the bottom margin of the tooth base (Figure 4B). Large nutritive foramina occur in a line on the lingual basal surface (Figures 3F, 4B). Labially the tooth root is smooth with only 3 or 4 nutritive foramina (Figure 4A).

The tooth root is thickest (labioliogually) at its junction with the crown and thins to a feather-edge along the lower margin (Figures 3E, 4C). Both labial and lingual root surfaces are approximately parallel for half the basal length and then the labial surface converges sharply toward the lingual surface to meet the latter slightly forward of the medial line of the tooth; resulting in the lower half of the tooth root being lingually prominent (Figures 3E, 4C). Lingually the tooth root is slightly concave from the anterior margin to the posterior margin (Figure 3B) which may be an accommodation for a replacement tooth.

Discussion
Taxonomic placement of the tooth is difficult as it shows few affinities to any known taxa, with perhaps the exception of the petalodonts and *Heteropetalus* Lund, 1977. The strong feature of the *Gondwanodus* tooth is the lingually prominent coronal basal margin, a feature shared only with petalodonts and *Heteropetalus*. Hansen (1985) has listed four basic aspects of external tooth morphology in petalodonts. Only two features of *Gondwanodus*, the lingually prominent coronal basal margin and a medially acuminate crown, are shared with the petalodonts. The lingually prominent coronal basal margin is imbricated in the petalodonts and petalodont crowns are labioliogually compressed. However these characters are absent in *Gondwanodus*. Additionally, there are no visible osteons on the surface of the crown and therefore no indication of tubular dentine which is a diagnostic character of the microscopic anatomy of petalodont teeth (Zangerl et al. 1993). The coronal basal margin of *Heteropetalus* is lingually prominent and like *Gondwanodus* is not imbricated (Lund, 1977). However, although the teeth of *Heteropetalus* show some variation depending on their position in the dentition, none of the illustrated tooth families (Zangerl 1981, figure 67A–D; Hansen, 1985, figure 12A–D; Lund, 1977, figure 10A–D) closely resemble *Gondwanodus*. The tooth is therefore sufficiently unique to be a new genus with a possible relationship to the petalodonts and *Heteropetalus*. There is a fifty million year interval between the occurrence of *Heteropetalus* in the Lower Carboniferous (Chesterian) and *Gondwanodus* in the Lower Permian (Sakmarian). It is possible that *Heteropetalus* is related to *Gondwanodus* and the lingually prominent coronal basal margin may be a derived character linking them, being extremely pronounced in the latter. Histological examination is presently not possible as the described specimen is the holotype and the only one known.

The lack of an open pulp cavity in this specimen precludes the possibility that it is perhaps a dermal denticle or cephalic spine which can be very tooth-like in appearance and structure (e.g. Maisey 1989, figure 32A–C). Additionally, it has a long root with nutritive foramina on the root surface.

Etymology
Named after the Irwin River where Fossil Cliff sediments are exposed.
Figure 3  A-F Condzuanodus iriuitu'iisis gen. et sp. nov. Holotype (actual tooth) WAM 987.1, from Fossil Cliff, in A, dorsolingual, B, dorsal, C, antero-dorsal, E, postero-lingual and F, lingual views. D, detail of cusp. Bar scales for A, B, C, E and F are 1 mm. Bar scale for D is 0.1 mm.
The robust morphology of the tooth suggests that it could withstand considerable forces and indicates a durophagous diet. The deep, wide, flaring root would have provided a solid attachment in the jaw tissue and suggests infrequent replacement (Hansen, pers. comm.). The acuminate cusp, albeit short, suggests a specialised puncturing function which possibly assisted in the splitting of hard exoskeletons rather than the crushing of brachiopod and pelecypod shells which would have required a pavement-like dentition. Therefore, it is envisioned that creatures such as small decapod crustaceans or phyllocarids may have been a food source for Gondwanodus. Fragments of crustacean shell have been found in the limestone of the Fossil Cliff Member.

ACKNOWLEDGEMENTS
I am most grateful to Dr Susan Turner of the University of Queensland for her encouragement, advice and comments on the specimen. Also to Dr John Long and Dr Ken McNamara of the Western Australian Museum for their continued help and advice. Darren Ferdinando of the Geological Survey of Western Australia for information on the environment of deposition of the Fossil Cliff sediments, unpublished stratigraphic information and for providing access to microvertebrate specimens from the University of Western Australia. Kate Trinajstic of the University of Western Australia is thanked for the SEM photography and constructive comments on the draft manuscript; Dr Michael Hansen of the Ohio
A new Early Permian elasmobranch

Geological Survey, U.S.A., for his comments on the specimen and information on petalodonts; and Dr Richard Lund of Adelphi University, U.S.A., for his helpful suggestions.

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Some Late Cambrian molluscs from Liaoning Province, China

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Abstract – *Pilina liaoningensis* sp. nov. is described from the Late Cambrian Wanwankou Member of the Fengshan Formation, Benxi, Liaoning, China. Muscle scars and other internal structures are preserved very well in the paratype; bifurcate bundle scars are described for the first time from the fossil Tergomya. This is the oldest known occurrence of *Pilina*. Three species of Late Cambrian gastropods, *"Maclurites" ulrichi* (Kobayashi), *Matherella walcotti* Kobayashi and *Lytospira wanwankouensis* sp. nov. are also described from the Late Cambrian of northeastern China. *Lytospira* has been previously reported in the Lower Ordovician to the Middle Silurian of North America and Europe.

INTRODUCTION

The fossil Tergomya and Gastropoda described and illustrated in this paper were collected in 1980 by Xu Jun-tao and his colleagues of the Nanjing Institute of Geology and Palaeontology, Academia Sinica. They are from the Wanwankou Member of the Fengshan Formation exposed in two sections. The Chiushukou section is located at the Qiushugou village of Niuxintai, northeastern Benxi County, Liaoning Province, and the Doufangkou section is near the Yingzi village of Huolianzhai, in the northern part of Benxi.

The collection contains four species placed in four genera: *Pilina liaoningensis* sp. nov.; *"Maclurites" ulrichi* (Kobayashi); *Matherella walcotti* Kobayashi and *Lytospira wanwankouensis* sp. nov. The first two taxa are from the Doufangkou section; *Matherella walcotti* and *Lytospira wanwankouensis* are from the Chiushukou section (Figure 1). Apparently among these fossils, *Pilina liaoningensis* represents the oldest known species of the genus; its excellently preserved muscle scars and other internal structures are highly significant.

GEOLOGICAL SETTING

Cambrian sediments, especially Upper Cambrian, are extensively distributed in Liaoning, Shandong and Shansi Provinces and Inner Mongolia in North China. The Upper Cambrian rocks are well developed and contain a diversity of fossils. Kobayashi (1931) established the Wanwankou Series in Taizihe Valley, Liaoning Province, to include the Wanwankou Limestone, Wanwankou Dolomite, Chiushukou Shale and Hsiapingkou Dolomite. He considered the Series to be Early Ordovician in age. Kobayashi (1933) studied the fauna, which included a great variety of molluscs from the Wanwankou Dolomite of the Wanwankou Series exposed in the Niuxintai Basin of Liaoning Province. In that work he described the following gastropods: *Helicotoma wanwankouensis* Kobayashi, *Matherella walcotti* Kobayashi, *Clisospira niuhsintaiensis* Kobayashi, *Archinacella wanwankouensis* Kobayashi, *Propitina bridgei* Kobayashi, *P. ampla* Kobayashi, *P. (?) sp., Sceiuella sp. indet., Stenotheca (?) munichurica* Kobayashi, *Sceiuella ulrichi* Kobayashi and *S. naticaformis* Kobayashi. Two decades later, after restudying the strata of the Taizihe Valley, Wang and others revised the age of the Wanwankou Limestone, Wanwankou Dolomite and Chiushukou Shale, and assigned those three formations to the Late Cambrian Fengshan Formation (Wang *et al.*, 1954; Lu, 1962; *Lu et al.*, 1974; *Chen et al.*, 1979, 1983; *Chen* and *Teichert*, 1983).

The Fengshan Formation in Liaoning Province is divided into three members, in ascending order: the Yenzhou Member, the Wanwankou Member and the Chiushukou Member (Wang *et al.*, 1954; Lu, 1962; *Lu et al.*, 1974; *Chen et al.*, 1979, 1983; *Chen* and *Teichert*, 1983). The Wanwankou Member is about 20 to 50 m thick, and is noteworthy for its rich fauna of cephalopods, rostroconchs, gastropods, trilobites, brachiopods and conodonts. It is composed mainly of stromatolitic limestone and stromatolitic dolomite, interbedded with intraformational limestone conglomerate (Chen and *Teichert*, 1983). The molluscs described herein are generally well preserved. Associated with them are the cephalopods *Sinocremoceras wanwankouense* (Kobayashi), *S. taizense* *Chen* and *Teichert* and *Wanwanceras peculiar* Kobayashi, and trilobites.
The fauna contains characteristic fossils of the Upper Cambrian which is widely distributed in the Upper Cambrian of Shandong, Anhui, and Zhejiang Provinces (Lu, 1962; Chen et al., 1979; Chen and Teichert, 1983; Chen et al., 1983).

Illustrated specimens are deposited in the Nanjing Institute of Geology and Palaeontology (NIGP), Academia Sinica.

**SYSTEMATIC PALAEONTOLOGY**

**Class Tergomya** Horný, 1965

**Order Tryblidiida Lemche, 1957**

**Superfamily Tryblidiacea Pilsbry, in Zittel-Eastman, 1899**

**Family Tryblidiidae Pilsbry, in Zittel-Eastman, 1899**

**Genus Pilina** Koken, in Koken and Perner, 1925

*Pilina liaoningensis* sp. nov.

Figures 2, 3a–i, 4a–e

**Material Examined**

**Holotype**

The holotype (NIGP 113849) shows the external surface covered with ornament.

**Other material**

The three paratypes, NIGP 113850–113852 are more or less complete to fragmentary, but all contribute information on the musculature.

**Type locality**

DoufangKou section exposed near Yingzi village, Huolianzhai, Benxi Liaoning Province, China (see Figure 1).

**Diagnosis**

Shell large, tryblidiform, elliptical in dorsal view. Protoconch symmetrically conical. Apex overhanging adapical margin. Surface ornamented with stout comarginal rugae, fine growth lines and radiating threads. Interior with eight metametric pairs of muscle scars, one pair of radular muscle scars, and other internal structures on dorsal side of steinkern.

**Description**

Shell large, elliptical in dorsal view. Protoconch small, about 5 mm wide, symmetrically conical in dorsal view, protruding strongly forward, broadly rounded in the basal part, slowly and gradually increasing in size away from the apex. Tip and external features of protoconch are not preserved (Figure 3c). Dorsum gently flattened, oblique toward the abapical margin, with greatest shell width just behind midlength. Abapical margin rounded; adapical margin narrowly rounded, though not known in detail. Lateral margins more broadly curved but also not known in detail.

Shell surface ornamented with comarginal rugae, growth lines and radiating threads. Comarginal rugae stout and evenly distributed, more than 20 in number, gradually becoming stronger from apex toward abapical margin, with the distance between rugae also gradually becoming wider. Growth lines
Figure 2  *Pilina lioungensis*, sp. nov. a, b. Paratype 113850. a, dorsal view, showing the serially arranged muscle scars on the right side of the dorsum, x 5. b, diagrammatical drawing of NIGP 113850: A-H = pedal retractor muscle scars; 1 = medio-pedal muscle scar; 2 = latero-pedal muscle scar; 3 + 4 = musculus branchialis and pallial muscle; ra. m. s. = radular muscle scars; s.g.c. = scar of gill cavity; b.m.f. = bifurcated muscle fibres, x 2.25.
Late Cambrian molluscs from China

rather fine, closely spaced. Radiating threads crossing rugae and growth lines to form a concellate sculpture.

In lateral view of steinkern (Figure 3g), apex protruding and overhanging adapical margin, dorsal side flattened and inclined gradually downward to the abapical margin. Dorsum of dorsal side flattened and inclined gradually scars are present raised above the general level of the steinkern. Scars are interpreted as one pair of radular muscle scars and eight metameric pairs of composite muscle scars (i.e. Figure 2 A to H), other interior shell marking are present.

Details of musculations

Radular muscle scars are largest and most pronounced of internal features. These scars are subelliptical in plan view, complex, being composed of more than thirty small scars, and situated one-third of distance between adapical margin and midline.

The A to C pairs of muscle scars are situated on both sides of the radular muscle scars. All three pairs of muscle scars are linked together in the anterior portion of the shell. The D to H pairs of muscle scars are discrete and are located in the posterior of the shell. They are all similar and nearly horseshoe-shaped (Figure 2). Each muscle scar can be divided into four parts; two larger and two smaller. Part (3) gradually becomes smaller and weaker from D to H coordinate with Part (4) which becomes larger and stronger and develops two small pits. Each muscle scar set but particularly in D to H, is flanked by eight or more small scars is distributed. These muscles extend outward and display a secondary, tertiary or more bifurcation.

In addition, on the outer sides of the muscle scars sets are smaller scars. These are on the outside of the main scars. Their placement is in the lateral gill cavities, extending backward from C to G pairs. The anterior pairs are thinner and shallower, than those toward the posterior which wider and deeper; these latter display a regular wave-like curvature.

As the adapical part of this internal mould has been slightly damaged, the muscle scars of the anterior body region are not completely known on this steinkern, there are three pairs of muscle scars on both sides of the anterior body region. The first pair being larger and rope-like in appearance, situated anterior to A to C pairs of muscle scars. The second pair are located near the anteriorly lateral side and are stripe-like in appearance and extend posteriorly. The third pair are subcircular, situated near the lateral margin and next to the second pair. Furthermore, between the stripe-like muscle scars and the subcircular muscle scars, there are five small grain-like muscle scars (Figures 2, 3f, g). On both sides of A to C pairs there are at least two pairs of muscle scars parallel to the radular muscle scars.

A broken steinkern is shown on Figure 3i. Preserved on the right of the inner side are five preserved muscle scars, which are similar in shape and size to the D–H pairs of muscle scars illustrated in Figure 2, 3f, g, h, 4a, b.

A more or less weathered specimen is figured in Figure 4c, d, e. It has the traces of the radular muscle scars, and the A to H muscle scar sets on the right side are clearer than those on the left side.

Dimensions (mm)

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Remarks

Species of *Pilina* have mainly been reported from the Upper Ordovician of the Baltic Region (Koken and Perner, 1925) and Oklahoma (Peel, 1977), and from the Middle Silurian of Gotland, Sweden (Lindström in Angelin and Lindström, 1880; Lindström, 1884). The new species of *Pilina* described herein represents the earliest record of the genus. The species is peculiar in its protoconch, more complex muscle scars and thereby differs from the all known species.

*Proplina* Kobayashi, 1933 is known from the Upper Cambrian to Lower Ordovician of North America and Northeast Asia. Musculature is more prominent in species of *Pilina*. *Proplina* has a higher more rounded cross-section than *Pilina*. Thus we felt justified in extending the downward range of *Pilina*.

Judging from the broadly flattened dorsum, the presence of eight pairs of pedal muscle scars, *Pilina liaoningensis* is similar to *Proplina sibeliusi*

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**Figure 3** *Pilina liaoningensis*, sp. nov., a–e, holotype NIGP 113849. a. dorsal view, showing comarginal rugae, radiating threads and growth lines; b. enlargement of ornament; c. anterior view, showing the symmetrical protoconch (black arrow); d. right-lateral view, showing profile and rugose comarginal ornament; e. oblique right-lateral view; f–h, paratype NIGP 113850. f. dorsal view, showing the eight metameric muscle scars and radular muscle scars; g. right-lateral view, showing the scars of gill cavity and other internal structures on the right side of the shell; h. oblique right-lateral view; i. paratype NIGP 113852, interior view of a substantial specimen, showing five muscle scars on the right side of the shell. Scales = (a, e, h) x 1.5; (b) x 10; (c, d, f, g) x 2; (i) x 4.
Late Cambrian molluscs from China

Stinchcomb (1986, p. 613, figs. 2.6-2.8, 3.11-3.13) from the Lower Ordovician Gasconade Formation of Missouri, U.S.A., but differs from the latter species in the shell being elliptical in dorsal view, in the flatter dorsal side, in the narrower A to C pairs of pedal muscle scars and in having bifurcated muscle fibres.

In some respects, particularly in the flatter dorsal side, this species resembles *Biptilina eufisae* Yochelson (1958, p. 10, figs. 5–9; Knight and Yochelson, 1960, p. 178, fig. 46–5; Wingstrand, 1985, p. 49, fig. 19) from the Lower Ordovician, Gasconade Formation of Missouri. That form is lower and flatter and its muscle scars have a more triangular shape.

**Horizon and locality**

Wanwankou Member of Fengshan Formation, at Doufangkou.

**Class** Gastropoda Cuvier, 1797  
**Order** Archaeogastropoda Thiele, 1925  
**Suborder** Macluritina Cox and Knight, 1960  
**Superfamily** Macluritacea Fischer, 1885  
**Family** Macluritidae Fischer, 1885  
**Genus** *Maclurites* LeSueur, 1818

**Remarks**

The type species of *Maclurites* is from the Middle Ordovician and the limits of the genus are not clear at this time. Thus the generic name is used in a quotational sense. This taxon does not seem to be closely allied to *Scaeogyna*.

**Diagnosis**

Spire depressed. Base flattened. Whorls increasing slowly in early stages, more abruptly in body whorl, embracing about half of penultimate whorl on basal surface. Width of body whorl about two times that of inner whorls. Approximately seven whorls at maturity. Pseudoumbilicus wide and deep, about one-half diameter of shell. Aperture ovate. Growth lines closely spaced.

**Description**

Shell of medium size, very low-spired, sinistral in orthostrophic orientation. Protoconch unknown. Whorls five to seven in number, increasing slowly and gradually in the early ones, abruptly in the body whorl, especially near the apertural region and embracing about one-half of the penultimate whorl on its basal surface. Width of the body whorl about two times that of the inner whorls and the height about two-thirds of the width. Basal surface slightly convex in early stages, gently rounded at maturity. Basal suture distinctly impressed. Outer whorl surface gently rounded, the juncture of basal and upper faces following the arc of a small circle. Upper surface inclined inward, following the arc of a circle of smaller diameter than the basal one. Pseudoumbilicus wide and deep, approximately one half the diameter of the shell. Pseudoumbilical walls inclined steeply downward. Aperture not well known, but generally ovate in shape. Surface of shell mainly smooth but faint lines of growth are present near aperture (Figure 4j, k). Operculum unknown.

**Dimensions (mm)**

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**Remarks**

The description is based on three specimens and one incomplete internal mould. The shell is characterized by a distinct, but very low-spired and rapidly expanded body whorl.

**Figure 4** a–e, *Pilina lioeningensis*, sp. nov. a–b, paratype NIGP 113850. a, b, dorsal views, enlargement of muscle scars; c–e, paratype NIGP 113851. c, dorsal view, showing the eight paired muscle scars on the right and left sides of the dorsum. d, e, right-lateral and left-lateral views, showing the muscle scars on the right and left sides of the shell. f, *Matherella walcotti* Kobayashi, abapertural view. NIGP 113857. g–k, "Maclurites" *ulrichi* (Kobayashi), g–h, apertural and top views, NIGP 113854; i, basal view, showing the depressed spire, NIGP 113855; j, k, basal and apertural views, showing the growth lines and the form of aperture, NIGP 113853. l–n, *LytoSpiro wamaiokouensis*, sp. nov., holotype NIGP 113858. l, apical view, m, n oblique apical views. Scales: (a) x 7.5; (b) x 4; (c, d, e) x 2; (f, i, j, k, l) x 1.5; (g, h, m, n) x 1.
In the general outline of the shell, in the well rounded outer surface, especially the wide pseudoumbilicus, this species resembles "Macurites" thomsonii Webers et al. (1992, p. 200, pl. 6, figs. 1-8; pl. 7, figs. 1-7), from the Upper Cambrian Minaret Formation of Heritage Range, West Antarctica. It differs from the Antarctic species in having a depressed spire, more slowly increasing early whorls and in the proportion between the height and the diameter of the shell and in the ovate aperture.

In some respects, this species is also closely allied to Macurites niuhsintaiensis Kobayashi (1931, p. 97, pl. 10, figs. 5a–c; Yu, 1961, p. 379, pl. V, figs. 10–12; pl. VIII, figs. 8–10; Yu et al., 1963, p. 86, pl. 25, figs. 4–6) from the Lower Ordovician Machiakou Formation of Niuxintai Basin, Liaoning. It is easily distinguished from M. niuhsintaiensis by its depressed spire, more rounded basal edge, more obtusely rounded umbilical edge and by the ovate form of the aperture.

Horizon and locality
Wanwankou Member of Fengshan Formation, at Doufangkou.

Family Scaevogyridae Wenz, 1938

Genus Matherella Walcott, 1913

Remarks
The genus Matherella Walcott, 1913 is Late Cambrian in age. It is widely distributed, having been originally described from the Upper Cambrian Hoyt Limestone of eastern New York and subsequently from the Upper Cambrian Minaret Formation of Heritage Range, West Antarctica (Webers et al., 1992).

Matherella walcooti Kobayashi, 1933

Figure 4f

Matherella walcooti Kobayashi, 1933, p. 261, pl. IV, fig. 7; pl. V, fig. 9.

Matherellina walcooti (Kobayashi): Knight 1941: 189, pl. 90, figs. a–c; Knight et al., 1960: 1187, Fig. 104–5; Yu et al., 1963: 97, pl. 27, figs. 12–13; Yu, 1987: 93, text-fig. 30a–b; 1990: 145.

Material Examined
One internal mould, NIGP 113857.

Diagnosis
High spired, trochiform, sinistral in orthostrophic orientation. Outer face slightly convex, sutures distinctly impressed. Surface ornamented with rugae.

Remarks
The specimen figured here agrees in general character with those described by previous authors. However, our specimen is larger than any previously illustrated for the taxon.

Horizon and locality
Wanwankou Member of Fengshan Formation, at Qiushugou.

Superfamily Euomphalacea de Koninck, 1881

Family Euomphalidaceae de Koninck, 1881

Genus Lytospira Koken, 1896

Remarks
This genus superficially resembles Ecculiocephalus Portlock, 1843, but differs in having a blunt, spiral angulation on or near the midline of the upper whorl surface.

To the best of our knowledge multiwhorled open-coiled gastropods have not been reported from beds as old as Upper Cambrian. Despite the limited amount of material we deem it worthwhile to name a species so as to emphasize the early development of this type of morphology.

Lytospira wanwankouensis, sp. nov.

Figure 4l–n

Material Examined
A single internal mould, NIGP 113858 (holotype).

Type locality
Chiushukou section, Niuxintai, Liaoning Province, China (see Figure 1).

Diagnosis
Shell discoidal, with blunt spiral angulation near midline of upper whorl. Whorls four to five in number, first two whorls in contact, but later ones openly coiled.

Description
Shell small and discoidal. Whorls four to five in number, the first two in contact, with later whorls open-coiled and rapidly increasing in size. A blunt, spiral angulation is near the midline of the upper whorl surface, sloping inward towards the inner whorl surface. Outer whorl surface is gently convex. Suture in the first two whorls is distinctly impressed. Surface of the steinkern is smooth. Aperture and the characters of base unknown. Growth lines unknown.

Remarks
According to previous records, the genus...
**Late Cambrian molluscs from China**

*Lytospira* occurs from the Lower Ordovician to the Middle Silurian in North America and Europe. The present record of the genus from north-east China thus extends the time-range of *Lytospira* back to the Late Cambrian.

In apical view, this species is somewhat similar to the type species *Lytospira angulata* (Lindström) (1884: 138, pl. XIII, figs. 36–38; Knight et al. 1960: 1191, fig. 107–6) from the Middle Ordovician of Sweden. *Lytospira vantwankeouensis* differs in having the whorls discoidal in the same plane and in having a more obtuse spiral angulation. It also shows some affinities to *Lytospira valida* Koken in Koken and Perner (1925, p.115, pl. XIII, fig. 3), but differs from the latter in having tightly coiled early whorls and a more concave inner whorl surface.

**Horizon and locality**
Wanwankou Member of Fengshan Formation, at Qushugou.

**DISCUSSION**

Tergomya are rare in the Fengshan Formation but *Pilina liaoningensis*, sp. nov. deserves special note because of its excellent preservation of the ornate shell, muscle scars and other internal structures, which projects like a raised platform in outlook, including one pair of radial muscle scars and eight metameric pairs of composite muscle scars (i.e. the A–H pairs of muscle scars) (Lemeche and Wingstrand, 1959). The overall shape shows a configuration similar to that of the type species *Pilina unguis* Lindström (Lindström, in Angelin and Lindström, 1880; Lindström, 1884) from the Middle Silurian of Gotland, Sweden and that of *P. cheyennica* Peel from the Upper Ordovician Keel Member of the Chimneyhill Limestone, Oklahoma (Peel, 1977).

The paired radial muscle scars in *P. liaoningensis* are well preserved and are the biggest in the muscular field. In detail these scars are subelliptical in plan view and very complex, composed of more than thirty small scars. The radial scars are situated high on the dorsum just about one-third of the distance along the length of the shell. In the type species *P. unguis* (Lindström), the radial muscle scars are nearly tadpole-shaped and smaller in size (Lindström, in Angelin and Lindström, 1880: 16, pl. II, figs. 10–14, excl. fig. 15; Lindström, 1884: 56, pl. I, figs. 33–37; pl. XIX, fig. 2; Knight, 1941: 246: 4, figs. 1–3; Knight and Yochelson, 1960: 178, Fig. 48–6; Lemeche and Wingstrand, 1959: 44, figs. 133, 134 162A–D; Wingstrand, 1985: 449, Fig. 19) while in *Pilina cheyennica* Peel, the radial muscle scars are subrectangular in shape (Peel, 1977, 117–121, text-figs. 1–3; Wingstrand, 1985: 46, fig. 19; Peel 1991: 7, fig. 3c).

The A to C muscle scars pairs are situated laterally both sides of the radial muscle scars closer to the shell margin. These three pairs of elongate muscle scars are linked together. The D to H pairs of muscle scars are located posterior to the midlength of the shell. They are all similar and nearly horse-shoe-shaped (Figure 2).

The recent *Neopilina galatheae* Lemeche (1957) has been studied in detail. (Lemeche 1957; Lemeche and Wingstrand 1959; Wingstrand 1985). According to Lemeche and Wingstrand (1959) each pedal retractor muscle can be divided into two parts: (1) and (2), we interpret D–H as pedal retractors in part because of their position and in part because of the similarity of the muscles to those of *Neopilina*. Even though we can discern four parts, the overall shape of the scars is basically bipartite. The same bipart division can be seen in the scar of *P. liaoningensis*. Latero-posteriorly on the D to H pairs of muscle scars there is a small distinct scar (part 3) is situated in the left corner and another clear small scar (part 4) is located at the right corner of each main muscle scar. We present that the two main biparts of each scar control: parts (1) and (2) control the foot and provide for clamping and crawling movement; parts (3) and (4) more likely control activity of gill lobes and pallial muscles. As noted part (3) tends to gradually become smaller and weaker from D to H; while part (4) becomes larger and stronger and has two small pits. In *P. unguis*, the A to C sets are bigger and wider than those in *P. liaoningensis*, and the D to H sets are subdivided into more than four smaller parts (Lemeche and Wingstrand 1959, figs. 133, 134). In *P. cheyennica* the A and B sets are coalesced, the C to H sets are not subdivided into the various minor scars.

The bundled impressions lateral to the pedal muscle scars appear unique. They show secondary and tertiary bifurcation and extend to the lateral margin. These do not stand in relief like the presumed pedal scars. It is possible that these are the marks of blood vessels. We doubt that blood vessels would be impressed into the shell. Our interpretation is that this muscle extends to edge of the mantle which would shape the contours of the lateral gill cavity.

The scars of the gill cavity are between the pedal muscle scars and the shell margins, and are another interesting structure in this species. They extend backward from C pair to G pair, the anterior ones being thinner and obscure, while those toward the posterior are wider and deeper, displaying a regular wave-like curvature. The concave curved surface is broader than the convex side, whereas in *P. cheyennica* the scars of the gill cavity are obscure.

In addition, there are at least three pairs of muscle scars on both sides of the anterior body region. The first pair being larger and rope-like in appearance, situated anterior to A to C pairs of muscle scars. The second pair are located near the anteriorly...
lateral side and are stripe-like in appearance and extend posteriorly. The third pair are subcircular, situated near the lateral margin and next to the second pair. Furthermore, between the stripe-like muscle scars and the subcircular muscle scars, there are five small grain-like muscle scars (Figures 2, 3f, g). On both sides of A to C pairs of muscle scar sets, there are at least two pairs of muscle scars parallel to the radular muscle scars.

The protoconch of Pilina liaoningensis sp. nov. is a small, symmetrical cone, protruding strongly forward (Figure 3c). Although external features and tip of the protoconch are not preserved, this specimen further establishes that the Tergomya have a symmetrical protoconch (Clarke and Menzies 1959; Menzies and Layton 1963; Peel 1977; Wingstrand 1985). In P. cheymonica (Peel 1977), from the Upper Ordovician, the protoconch is a small mamillate protuberance.

Ornament in Pilina varies among species. In P. liaoningensis, the outer surface is covered with more than twenty stout and evenly distributed comarginal rugae, the interspaces between the rugae being covered with fine lines of growth. This ornament is crossed by radiating threads, resulting in a cancellate pattern. In P. unguis, the ornament comprises growth lines and faint, widely spaced grooves, where as in P. cheymonica, the outer surface is covered with lamellar growth increments, which may be irregularly rugose.

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A catalogue of Recent echinoderm type specimens in the Western Australian Museum, Perth

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Abstract - This is the first published catalogue of all echinoderm type material lodged in the Western Australian Museum of Natural Science. Seventy nine echinoderm species of the classes Crinoidea, Asteroidea, Ophiuroidea, Echinoidea and Holothuroidea are represented in the type collection. The earliest echinoderm species described in this collection date from the Hamburg South-Western Australian Research Expedition (Koehler, 1907). Information is presented here on the registration and collection details of the specimens, and habitat information is given where available.

INTRODUCTION

The echinoderm collection held in the Department of Aquatic Zoology, Museum of Natural Science, Western Australian Museum (WAM), Perth, consists of over 21,500 registered specimen lots. This material includes type specimens of 79 species of recent Echinoderms. The first lists of type specimens in the WAM were documented in the Museum's Annual Reports commencing with Part 1 in 1959-60. A list of 19 echinoderm holotypes was included in part 3 (Anon. 1961–62) with corrections to two species names in part 7 (1965–66), one of them with a spelling error. The lists were discontinued after Part 10 (1968–69). No further documentation of echinoderm types has occurred until this publication. This catalogue of 79 species of Recent echinoderms includes type material of three crinoids; 32 asteroids; 27 ophiuroids, nine echinoids and eight holothuroids. Of these, 34 are holotypes of nominal species, some of which have since fallen into synonymy. The remainder are paratypes, paralectotypes or syntypes.

The first overseas expedition to deposit type material in the WAM was the Hamburg SW Australian Expedition of Michaelsen and Hartmeyer (1905) which collected extensively in Shark Bay and the south-west of the state. Type material of two species of ophiuroids from their collection, described by Koehler (1907), were the first echinoderms represented in the type collection. The small collection in the WAM was considerably augmented by the efforts of the then Keeper of Natural History, W.B. Alexander, who accompanied the Federal Fisheries Investigation Ship *Endeavour* on two trawling cruises off the mid-west coast of Western Australia. New species from these and earlier collections were described by A.H. Clark (1914) and H.L. Clark (1914, 1916). H.L. Clark (1923) also described echinoderms from the Houtman Abrolhos but deposited types elsewhere. Clark, supported by the Carnegie Institution, Harvard University and the Australian National Research Council made two extended collecting trips to Australia in 1929 and 1932 (CAH Expedition) amassing over 11,000 specimens representing 422 species from the coast and shallow water of most of the Australian continent. Type material of 32 nominal species and three varieties from these expeditions was deposited in the WAM (H.L. Clark, 1938). Many of the type specimens from Clark’s expeditions were deposited in the Museum of Comparative Zoology (MCZ), Harvard, with some representatives deposited in other Australian Museums. Clark’s work on Australian echinoderms culminated in his monograph (H.L. Clark, 1946) on the composition, zoogeographic affinities and origins of the Australian echinoderm fauna which remained the only comprehensive listing of the fauna until Rowe and Gates (1995). Since the 1960s, fieldwork by staff of this Museum in Australia and elsewhere, has resulted in the deposition of type specimens by Rowe, Baker, Marsh and others.

In this paper, the taxonomic sequence of the classes follows Clark and Rowe (1971) and class names are those in general current usage (Rowe and Gates, 1995). Below classes the classification followed here is predominantly that of the “Treatise on Invertebrate Paleontology” (Moore, 1966; Moore and Teichert, 1978). Within the Asteroidea changes since 1966 relevant to this catalogue include the erection of a new family (Asterodiscidae) in the order Valvatida (Rowe, 1977a) and the transfer of the family Asterinidae from the order Spinulosida to Valvatida (Blake, 1981). Since there is ongoing debate as to the

Families, genera and species are arranged alphabetically within each order. The original generic and species assignment with author and date of the material is presented. If the original generic assignment has been changed or the species has been synonymised these changes are given beneath the original name.

In the majority of cases, two WAM registration numbers are given. The first, with the prefix WAM is the original registration number and the second, provided in square brackets with the prefix WAM Z, is the new registration number linked to the WAM computer database. An electronic sequential numbering system has been adopted to alleviate duplication of old registration numbers in the future, as these included only the last two digits of the year in which the specimens were registered. The prefix Z distinguishes the registration numbers of the Marine Invertebrate Zoology section from those of other sections within the WAM. Where a specimen was not registered previously, the registration number has the WAM Z prefix without square brackets. The number of specimens, and the method of storage, are given in parentheses after the registration number. Specimens that are described as 'wet' are stored in 70 % ethanol. When latitudes and longitudes have not been quoted in the reference or on the specimen label, they are supplied in square brackets. Distances and depths are cited when provided, and their metric conversion appears in square brackets. Any inconsistencies between the label, registration catalogue or published information are noted under 'Remarks'. Additional information considered useful to researchers, such as the condition of the specimens, is also presented under 'Remarks'.


Class CRINOIDEA Miller, 1821
Order COMATULIDA A.H. Clark, 1908
Family Calometridae A.H. Clark, 1911
Genus Neometra A.H. Clark, 1912

Neometra conaminis A.H. Clark, 1914


Material Examined

?Synotypes number WAM 3-64 (4; wet) [new registration number: WAM Z 1864].

Locality: Between Fremantle [32°03'S, 115°45'E] and Geraldton [28°46'S, 114°37'E], Western Australia, 80-120 fathoms [146-219 m] depth, June 1912, W.B. Alexander on F.I.S. Endeavour.

Remarks

A.H. Clark (1914) based his species description on a type specimen and noted that there were three other specimens “all with 20 arms and all resembling the type”. In fact four specimens that comply with his description are held in the WAM and one further specimen, labelled cotype, is in the NMNH. The label with the WAM specimens is in H.L. Clark’s handwriting and does not indicate the type status of the material, hence the query before the syntype designation given above. This material, which has always been held with the type collection, is the only material of Neometra conaminis of this age held in the WAM, and we suspect it is type material but cannot unequivocally confirm its status. Rowe and Gates (1995) indicate that the holotype is in the WAM but do not give a registration number.

Neometra gorgonia A.H. Clark, 1914


Material Examined

Holotype number WAM 14-62 (1; wet) [new registration number: WAM Z 1865].

Paratypes number WAM 4947 (3; wet) [new registration number: WAM Z 1866].

Locality: Between Fremantle [32°03'S, 115°45'E] and Geraldton [28°46'S, 114°37'E], Western Australia, trawled at 80-120 fathoms [146-219 m] depth, June 1912, W.B. Alexander on F.I.S. Endeavour.

Remarks

A.H. Clark (1914) did not designate paratypes but refers to a total of seven specimens, one of which was the holotype. No Museum registration numbers were provided in the publication. The WAM holds the holotype and three paratypes, indicated on the original labels. One of the paratypes is damaged. A.H. Clark (1914) mentions the specimens have “purple bars” but on the original label the colour is given as white with yellow or purple bars.
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Family Comasteridae A.H. Clark, 1908

Genus Oxycomanthus Rowe, Hoggett, Birtles and Vail, 1986

Oxycomanthus niuelleri Rowe, Hoggett, Birtles and Vail, 1986

Oxycomanthus niuelleri Rowe, Hoggett, Birtles, and Vail, 1986: 257-259, figure 9F.

Material Examined

Holotype number WAM 137-79 (1; dry) [new registration number: WAM Z 1867].
Locality: Island on E side of Lucky Bay, Recherche Archipelago, 34°01’S, 122°15’E, Western Australia, rotenone station 4 m depth, 14 March 1978, B. Hutchins.

Paratype number WAM 74-80 (1; dry) [new registration number: WAM 1868].

Remarks
The arms of the holotype are damaged, and some of the tips of the arms of the paratype are missing.

Class ASTEROIDEA de Blainville, 1830

Order PAXILLOSIDA Perrier, 1884

Family Astropectinidae Gray, 1840

Genus Ctenophaster Fisher, 1906

Ctenophaster marquesensis Marsh, 1974


Material Examined

Paratype number WAM 24-72 (1; dry) [new registration number: WAM Z 1735].
Locality: Station NH XV haul 2 (8°50’S, 140°15’W), 1.5 miles S of Haopu Bay, Nuku Hiva, Marquesas Islands, South Pacific, dredged on sand at 43-45 fathoms [79-82 m] depth, 22 September 1967, B.R. Wilson et al. on Pele.

Paratype number WAM 25-72 (1; dry) [new registration number: WAM Z 1736].
Locality: Station TH 1 haul 1 (10°00’S, 139°10’W), Tahuata Island, Marquesas Islands, South Pacific, dredged on coarse yellow sand at 45 fathoms [82 m] depth, 28 September 1967, B.R. Wilson et al. on Pele.

Paratypes number WAM 26-72 (1; dry) [new registration number: WAM Z 1737]. WAM 27-72 (1; dry) [new registration number: WAM Z 1738].
Locality: Station TH 1 hauls 2-7 (10°00’S, 139°10’W), Tahuata Island, Marquesas Islands, South Pacific, dredged on yellow sand and broken shell at 36-45 fathoms [66-82 m] depth, 28 September 1967, B.R. Wilson et al. on Pele.

Paratype number WAM 28-72 (1; dry) [new registration number: WAM Z 1739].
Locality: Station TH X, haul 1 (9°52’S, 139°4.7’W), Haava Strait, between Tahuata Island and Hiva Oa, Marquesas Islands, South Pacific, dredged on sand at 40 fathoms [73 m] depth, 1 October 1967, B.R. Wilson et al. on Pele.

Remarks
The specimens WAM 24-72, 25-72 and 26-72 all have one or more arm tips damaged. The complete station list for this expedition is given in Devaney (1974).

Order VALVATIDA Perrier, 1884

Family Archasteridae Viguié, 1878

Genus Archaster Müller and Troschel, 1840

Archaster laevis H.L. Clark, 1938

Archaster laevis H.L. Clark, 1938: 75-77, plate 17, figure 2.

Material Examined

Paratypes number WAM 64-39 (1; dry) [new registration number: WAM Z 1700]; WAM 65-39 (1; dry) [new registration number: WAM Z 1701].
Locality: Broome [17°58’S, 122°14’E], Western Australia, at 5-8 fathoms [9-15 m] depth, June 1932, H.L. Clark et al.

Remarks
Sukarno and Jangoux (1977) reported this species as a synonym of Archaster angulatus Müller and Troschel, 1842. Although Clark (1938) did not designate any paratypes the original label is marked paratypes. A note on the label says: “also Fremantle District, La Grange, Roebuck Bay”. One specimen has a damaged arm.

Family Asterinidae Gray, 1840

Genus Asterina Nardo, 1834

Asterina alba H.L. Clark, 1938

Material Examined

**Asterina corallicola** Marsh, 1977


_Asterina lutea_ H.L. Clark, 1938

_(junior synonym of Asterina sarasini (de Loriol, 1897))_

_Asterina lutea_ H.L. Clark, 1938: 153–155, plate 12, figure 2.

_Asterina variabilis_ H.L. Clark, 1938

_(junior synonym of Nepanthia belcheri (Perrier, 1875))_


Genus *Nepanthia* Gray, 1840

_Nepanthia fisheri_ Rowe and Marsh, 1982

_Nepanthia gracilis_ Rowe and Marsh, 1982

_Nepanthia variabilis_ H.L. Clark, 1938

Material Examined

**Paratypes** number WAM 95-39 (1; dry) [new registration number: WAM Z 1702]; WAM 96-39 (1; dry) [new registration number: WAM Z 1703].

Locality: Ned’s Beach, Lord Howe Island [31°31’S, 159°04’E], Tasman Sea, under rock fragment, April 1932, H.L. Clark _et al._

**Paratypes** number WAM 97-39; WAM 98-39 (1; dry) [new registration number: WAM Z 1705].

Locality: Broome [17°58’S, 122°14’E], Western Australia, August/September 1929, H.L. Clark _et al._, CAH Expedition.

**Paratypes** number WAM 101-78 (1; dry) [new registration number: WAM Z 1707].

Locality: West Banguey Channel [7°30’N, 117°15’E], NE of Sabah, E Malaysia, dredged in mud at 25 fathoms [46 m] depth, 11 March 1964, B.R. Wilson on _Pele._

Remarks

The colour of the holotype is noted as blue/grey on the label.

_Nepanthia gracilis_ Rowe and Marsh, 1982

_Nepanthia fisheri_ Rowe and Marsh, 1982: 103–106, figures 1, 4A–C, 5D–11, 6G.

Material Examined

_Holotype_ number WAM 102-78 (1; dry) [new registration number: WAM Z 1706].

Locality: 14 km and 242° from Zal Island, SW of Pearl Bank, Sulu Archipelago [6°10’N, 120°45’W], Philippines, dredged at 55–60 fathoms [100–110 m] depth with many sponges, 22 February 1964, B.R. Wilson on _Pele._

**Paratypes** number WAM 104-78 (1; dry) [new registration number: WAM Z 1709].

Locality: 15 km and 242° from Zal Island, SW of Pearl Bank, Sulu Archipelago, [6°10’N, 120°45’E], Philippines, dredged at 55–60 fathoms [100–110 m] depth with many sponges, 22 February 1964, B.R. Wilson on _Pele._

Remarks

The collection date is given as February on the specimen labels, but printed in error as November in Rowe and Marsh (1982).

_Nepanthia variabilis_ H.L. Clark, 1938

_(junior synonym of Nepanthia belcheri (Perrier, 1875))_


Material Examined

**Paratypes** number WAM 119-39 (1; dry) [new registration number: WAM Z 1710]; WAM 120-39 (1; dry) [new registration number: WAM Z 1711].

Locality: 14 km and 242° from Zal Island, SW of Pearl Bank, Sulu Archipelago, [6°10’N, 120°45’E], Philippines, dredged at 55–60 fathoms [100–110 m] depth with many sponges, 22 February 1964, B.R. Wilson on _Pele._

**Paratypes** number WAM 103-78 (1; dry) [new registration number: WAM Z 1708].

Locality: 14 km and 242° from Zal Island, SW of Pearl Bank, Sulu Archipelago, [6°10’N, 120°45’W], Philippines, dredged at 55–60 fathoms [100–110 m] depth with many sponges, 22 February 1964, B.R. Wilson on _Pele._

Remarks

Rowe and Marsh (1982) reported this species as a synonym of _Nepanthia belcheri_ (Perrier, 1875). Although no paratypes were designated by Clark (1938) the specimens are labelled paratype in Clark’s handwriting. Rowe and Gates (1995) did not record the paratype specimen WAM 120-39.
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Genus Paraneanthia Fisher, 1917

Paraneanthia rosea H.L. Clark, 1938


Material Examined
Paratypes number WAM 16459-16468 (5; dry) [new registration number: WAM Z 1714].
Locality: Bathurst Point, Rottnest Island [32°00'S 115°33'E], Western Australia, 19 December 1929, L. Glaubert.

Remarks
The catalogue indicates ten specimens (16459-16468) but only five are now present. Although Clark (1938) did not designate paratypes the specimens are labelled as such on the original label. Rowe and Gates (1995) list the paratype numbers as 164/169-38 but these numbers are not correct and appear to be a misinterpretation of the original registration numbers given above.

Genus Parasterina Fisher, 1908

Parasterina occidentalis H.L. Clark, 1938
(junior synonym of Nepanthia troughtoni (Livingstone, 1934))


Material Examined
Paratype number WAM 606-31 (1; dry) [new registration number: WAM Z 1713].
Locality: Cottesloe [31°59'S, 115°45'E], Western Australia, date and collector unknown.

Remarks
A.M. Clark (1956) reported this species as a synonym of Nepanthia troughtoni (Livingstone, 1934). Clark (1938) did not designate any paratypes but these two specimens are labelled paratypes in H.L. Clark's handwriting. The colour of both specimens is given as red on the original labels.

Genus Patiriella Verrill, 1913

Patiriella parvivipara Keough and Dartnall, 1978

Material Examined
Paratype number WAM 540-77 (1; wet) [new registration number: WAM Z 1720].
Locality: Smooth Pool near Point Westall [32°55'S 134°04'E], South Australia, 19 September 1975, H.A. Scarle.

Family Asterodiscidae Rowe, 1977a

Genus Asterodiscides A.M. Clark, 1974

Asterodiscides culcitulus Rowe, 1977a

Asterodiscides culcitulus Rowe, 1977a: 193–197, figure 1.

Material Examined
Holotype number WAM 1063-74 (1; dry) [new registration number: WAM Z 1722].
Locality: Station DM 1/70/104 (30°29'S, 114°12'E), SW of Dongara, Western Australia, dredged at 60 fathoms [110 m] depth, sponge and bryozoa, 8 December 1970, B.R. Wilson et al. on H.M.A.S. Diamantina.

Paratypes number WAM 1116-74 (9; wet) [new registration number: WAM Z 1723].

Remarks
Rowe (1977a) indicates eleven paratypes but only nine now remain in the collection.

Asterodiscides macroplax Rowe, 1985

Asterodiscides macroplax Rowe, 1985: 536–540, figure 1, plate 2D–F, plate 3A–D.

Material Examined
Holotype number WAM 186-78 (1; dry) [new registration number: WAM Z 1726].

Paratype number WAM 188-78 (1; dry) [new registration number: WAM Z 1727].
Locality: E side of Goss Passage [28°29'S, 113°46'E], Wallabi Group, Houtman Abrolhos Islands, Western Australia, 30–36 m depth, sand, 6 April 1978, C. Bryce.

Paratype number WAM 48-81 (1; dry) [new registration number: WAM Z 1728].
Locality: Hummock Island [28°48'S, 114°02'E], Zeewyck Channel, Houtman Abrolhos Islands, Western Australia, dredged at 20–22 fathoms [37–40 m] depth, 10 to 22 November 1980, D. Heald.

Paratype number WAM 405-80 (1; dry) [new registration number: WAM Z 1729].
Locality: Station SO 1/79/09 (20°17'S, 116°01'E to 20°18'S, 116°00'E), ENE Montebello Islands, Western Australia, otter trawl at 60 m depth, 2 December 1979, L. Marsh and S. Slack-Smith on R.V. Saela.

*Paraixtpes* number WAM 59-80 (2; dry) [new registration number: WAM Z 1730].

Locality: station SO 1/79/23 (19°54'S, 116°02'E to 19°55'S, 116°00'E), NE of Montebello Islands, Western Australia, trawled at 76-78 m depth with many large sponges, 3 December 1979, L. Marsh and S. Slack-Smith on R.V. Saela.

Remarks
The locality of WAM 48-81 is given incorrectly as Hommock Island and the final longitude of the trawl in which WAM 405-80 was collected is given incorrectly as 166°00'E, instead of 116°00'E, in Rowe (1985).

*Asterodiscides pinguiiculis* Rowe, 1977a
*Asterodiscides pinguiiculis* Rowe, 1977a: 204–206, figure 4H–J.

Material Examined
*Holotype* number WAM 1079-74 (1; dry) [new registration number: WAM Z 1731].


*Asterodiscides soelae* Rowe, 1985
*Asterodiscides soelae* Rowe, 1985: 547–550, figure 1, plate 4A–F, 5A.

Material Examined
*Holotype* number WAM 191-78 (1; dry) [new registration number: WAM Z 1732].

Locality: W side of Goss Passage and about 100 m S of Long Island [28°29'S, 113°46'E], Wallabi Group, Houtman Abrolhos, Western Australia, 110–120 feet [33–36 m] depth, sand and rubble, 17 April 1978, L. Marsh and S. Slack-Smith.

*Paratype* number WAM 190-78 (1; dry) [new registration number: WAM Z 1733].


*Paratype* number WAM 382-80 (1; dry) [new registration number: WAM Z 1734].

Locality: Station SO1/79/22 (19 54'S, 116°02' to 19°55'S, 116°00'E ), E NE: of Montebello Islands, Western Australia, otter trawl at 76–78 m depth with sponges, 3 December 1979, L. Marsh and S. Slack-Smith on R.V. Saela.

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Family Goniasteridae Forbes, 1841

Genus *Pentagonaster* Gray, 1840

*Pentagonaster stibarus* H.L. Clark, 1914 (junior synonym of *Pentagonaster dubeni* Gray, 1840)


Material Examined
*Holotype* number WAM 4916 (1; dry) [new registration number: WAM Z 1743].

*Paratype* number WAM 4916 (1; dry) [new registration number: WAM Z 1744].

Locality: Between Fremantle [32°03'S, 115°45'E] and Geraldton [28°46'S, 114°37'E], Western Australia, 40–100 fathoms [73–183 m] depth, June 1912, W.B. Alexander on F.L.S. Endeavour.

Remarks
H.L. Clark (1914) designated the larger of these two specimens, both at that time with the same registration number, as the holotype. This species was synonymised with *Pentagonaster dubeni* Gray, 1840 by H.L. Clark (1946).

Genus *Stellaster* Gray, 1840

*Stellaster megaloprepes* H.L. Clark, 1914 (junior synonym of *Stellaster princeps* Sladen, 1889)


Material Examined
*Holotype* number WAM 4030 (1; dry) [new registration number: WAM Z 1745].

Locality: Off Port Hedland [20°18'S, 118°35'E], Western Australia, date and collector unknown.

Remarks
This species was synonymised with *Stellaster princeps* Sladen, 1889 by H.L. Clark (1938). The tips of two of the arms of the specimen are damaged.

Family Ophidiasteridae Verrill, 1867

Genus *Andora* A.M. Clark, 1967

Subgenus *Andora* (Dorana) Rowe, 1977b

*Andora* (Dorana) *wilsoni* Rowe, 1977b


Material Examined
*Holotype* number WAM 1054-74 (1; dry) [new registration number: WAM Z 1746].

Remarks
This species was synonymised with *Stellaster princeps* Sladen, 1889 by H.L. Clark (1938). The tips of two of the arms of the specimen are damaged.
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Remarks
The collection date is given as February on the specimen label, but printed in error as November in Rowe (1977b). The tip of one arm of the specimen has broken off.

Genus *Bimaster* Doderlein, 1896
*Bimaster variegatus* H.L. Clark, 1938


Material Examined
Paratypes number WAM 18-31 to 22-31 (5; dry) [new registration number: WAM Z 1747].
Locality: Bathurst Point [32°00′S, 115°33′E], Rottnest Island, off Fremantle, Western Australia, 5 January 1931, L. Glauert.

Remarks
The catalogue indicates five specimens but eight were present in one lot marked paratypes in H.L. Clark’s handwriting. Young specimens were included in the lot but H.L. Clark did not consider these juveniles to be paratypes (Marsh, 1991). This material has now been separated into large (paratypes) and small (non paratype) material. The latter specimens have the number WAM Z1748.

Genus *Ferdina* Gray, 1840
*Ferdina sadhensis* Marsh and Campbell, 1991


Material Examined
Paratype number WAM 427-90 (1; dry) [new registration number: WAM Z 1752].
Locality: Hoones Bay, E of Marbat, [Mirbat 16°58′N, 54°43′E], Dhofar, Sultanate of Oman, 5 m depth, 8 April 1988, M. Morrison.

Genus *Heteronardoa* Hayashi, 1973
*Heteronardoa diamantinae* Rowe, 1976


Material Examined
Holotype number WAM 1762-74 (1; dry) [new registration number: WAM Z 1755].
Locality: Station DM 1/64/17 off Point Cloates, Western Australia, (22°59.7′S, 113°25.5′E), 70 fathoms [128 m] depth, beam trawl, large sponges sheltering crabs, prawns, starfish, and urchins, 31 January 1964, B.R. Wilson et al. on H.M.A.S. Diamantina.

Genus *Linckia* Nardo, 1834
*Linckia tyloplax* H.L. Clark, 1914 (currently *Hacelia tyloplax* H.L. Clark, 1914))


Material Examined
Holotype number WAM 4931 (1; dry) [new registration number: WAM Z 1753].
Locality: Between Fremantle [32°03′S, 115°45′E] and Geraldton [28°46′S, 114°37′E], Western Australia, 80–120 fathoms [146–219] m depth, June 1912, W.B. Alexander on F.I.S. Endeavour.

Remarks
This species was reassigned to the genus *Hacelia* Gray, 1840 by Marsh (1976) without comment, and later confirmed by Rowe and Gates (1995). H.L. Clark (1914) notes that there were two specimens with the WAM no. 4931 and the larger of these was the holotype. According to the dimensions given by Clark, the remaining WAM specimen is the holotype, and additionally is labelled as such in Clark’s handwriting. The second specimen to which he referred is in the MCZ Dry Collection (MCZ#2215) and labelled cotype (syntype) (F.J. Collier, personal communication), but should be regarded as a paratype (ICZN 1985 Recommendation 73D).

Genus *Paraferdina* James, 1973
*Paraferdina sohariae* Marsh and Price, 1991


Material Examined
Holotype number WAM 78-90 (1; wet) [new registration number: WAM Z 1756].
Paratype number WAM 79-90, (1; wet) [new registration number: WAM Z 1757].
Locality: Station A/1 Deumba Gala, Galle [6°0′N, 80°13′E], Sri Lanka, on rock, 12–15 m, 25 January 1981, A.R.G. Price et al. on the Sindbad Voyage.

Family Oreasteridae Fisher, 1911
Genus *Anthenea* Gray, 1840

*Anthenea elegans* H.L. Clark, 1938

Material Examined
Paratype number WAM Z 1758 (1; dry).
Locality: Broome [17°58'S, 122°14'E], Western Australia, 5-8 fathoms [9-15 m], June 1932, H.L. Clark et al.

Remarks
The label states paratype in H.L. Clark's handwriting but this specimen had not been registered before 1998.

**Anthenea obesa** H.L. Clark, 1938

*Anthenea obesa* H.L. Clark, 1938: 127-128, plate 19, figure 1.

Material Examined
Holotype number WAM 4920 (1; dry) [new registration number: WAM Z 1760].
Locality: Off Geraldton [28°46'S, 114°37'E], Western Australia, dredged at 29 fathoms [53 m] depth, date and collector unknown on F.L.S. Endeavour.

Genus *Ciulcitaster* H.L. Clark, 1914

*Ciulcitaster anamesus* H.L. Clark, 1914 (junior synonym of *Halityle regularis* Fisher, 1913)


Material Examined
Holotype number WAM 13-62 (1; dry) [new registration number: WAM Z 1761].
Locality: Western Australia, date and collector unknown.

Remarks
H.L. Clark (1914) states that there was no information with this specimen but it was thought to have been collected on the coast of Western Australia. He does not give the WAM number in the publication. *Ciulcitaster* was synonymised with *Halityle* by Fisher (1919) and the species synonymised with *Halityle regularis* Fisher, 1913 by Doderlein (1935). Baker and Marsh (1976) review the species.

Genus *Goniodiscaster* H.L. Clark, 1909

*Goniodiscaster acanthodes* H.L. Clark, 1938

*Goniodiscaster acanthodes* H.L. Clark, 1938: 84-87, plate 5, figure 2.

Material Examined
Paratype number WAM 68-39 (1; dry) [new registration number: WAM Z 1759].

Locality: Broome [17°58'S, 122°14'E], Western Australia, dredged at 7-8 fathoms [13-15 m] depth on sand, June 1932, H.L. Clark.

Remarks
H.L. Clark (1938) did not designate a paratype but the original label is marked paratype.

Genus *Nectria* Gray, 1840

*Nectria saoria* Shepherd, 1967

*Nectria saoria* Shepherd, 1967: 475-478, figures 1, 2.

Material Examined
Paratype number WAM 8-64 (1; dry) [new registration number: WAM Z 1762].
Locality: Hamelin Bay [34°12'S, 115°01'E], near Cape Leeuwin, Western Australia, on jetty piles, 30 December 1961, B.R. Wilson and S. Slack-Smith.

*Nectria wilsoni* Shepherd and Hodgkin, 1965

*Nectria wilsoni* Shepherd and Hodgkin, 1965: 119-121, figure 1.

Material Examined
Holotype number WAM 3-65 (1; dry) [new registration number: WAM Z 1763].
Locality: Reef off Sorrento Beach [31°50'S, 115°04'E], near Perth, Western Australia, one mile offshore, 9 m depth, 25 December 1958, B.R. Wilson and L. Marsh.

Paratype number WAM 2-62 (1; dry) [new registration number: WAM Z 1768].
Locality: Off Beagle Island, Western Australia, (29°50'S, 114°52'E), March 1961, Poole brothers on R.V. Bluefin.

Paratype number WAM 1-65 (1; dry) [new registration number: WAM Z 1769].
Locality: Dunsborough, [33°36'S, 115°06'E], Western Australia, 55 feet [17 m] on limestone reef, 15 April 1963, B.R. Wilson.

Paratype number WAM 2-65 (1; dry) [new registration number: WAM Z 1769].
Locality: Reef off Sorrento Beach [31°50'S, 115°45'E], near Perth, Western Australia, on Posidonia, B.R. Wilson.  
Paratype number WAM 4-65 (1; dry) [new registration number: WAM Z 1770].  
Locality: Reef off Sorrento Beach [31°50'S, 115°45'E], near Perth, Western Australia, 21 December 1963, B.R. Wilson.  
Paratype number WAM 5-65 (1; dry) [new registration number: WAM Z 1771].  
Locality: Reef off Sorrento Beach [31°50'S, 115°45'E], near Perth, Western Australia, 18 feet [5.5 m] depth, on Posidonia near limestone reef, 23 November 1963, B.R. Wilson.

Remarks  
WAM 18-59 was dark red in colour, WAM 19-59 was orange and WAM 3-62 was bright red with mauve markings. Shepherd and Hodgkin (1965) refer to some of the material, WAM 2-65 and 4-65 as being collected from Sorrento reef near Fremantle, and WAM 5-65 and the holotype WAM 3-65 from Sorrento Beach. All these specimens were collected from the same locality, reef off Sorrento Beach north of Perth.

Order SPINULOSIDA Perrier, 1884  
Family Echinasteridae Verrill, 1867  
Genus Echinaster Müller and Troschel, 1840  
Echinaster arcystatis H.L. Clark, 1914  

Material Examined  
Holotype number WAM 4918 (1; dry) [new registration number: WAM Z 1741].  
Locality: Between Fremantle [32°03'S, 115°45'E] and Geraldton [28°46'S, 114°37'E], Western Australia, June 1912, W.B. Alexander on F.I.S. Endeavour.

Echinaster varicolor H.L. Clark, 1938  

Material Examined  
Paratype number WAM 125-39 (1; dry) [new registration number: WAM Z 1742].  
Locality: Vicinity of Broome [17°58'S, 122°14'E], Western Australia, 7-8 fathoms [13-15 m] depth, June 1932, H.L. Clark et al.

Remarks  
Although Clark (1938) did not designate any paratypes the original label is marked paratype in Clark's handwriting; some of the label is worn and cannot be deciphered.

Order FORCIPULATIDA Perrier, 1884  
Family Asteriidae Gray, 1840  
Genus Smilasterias Sladen, 1889  
Smilasterias multipara O'Loughlin and O'Hara, 1990  
Smilasterias multipara O'Loughlin and O'Hara, 1990: 311-315, figures 2, 3, plate 1A-B.

Material Examined  
Paratypes number WAM 428-86 (5; wet) [new registration number: WAM Z 1721].  
Locality: Off Jurien Bay [30°18'S, 115°00'E], Western Australia, 80-100 fathoms [146-183 m] depth, June 1912, W.B. Alexander on F.I.S. Endeavour.

Remarks  
Baker (1980) reported this species as a synonym of Astrobrachion adhaerens (Studer, 1884). Although H.L. Clark (1938) indicates there are two specimens with the number WAM 4925, only the holotype is in the collection. The paratype is in the MCZ collections, MCZ#3669 (Baker, 1980).

Ophiocreas rhabdotum H.L. Clark, 1914  
Ophiocreas rhabdotum H.L. Clark, 1914: 156.

Material Examined  
Holotype number WAM 4926 (1; wet) [new registration number: WAM Z 1953].  
Locality: Off Jurien Bay [30°18'S, 115°00'E],
Western Australia, 80–100 fathoms [146–183 m] depth, June 1912, W.B. Alexander on F.I.S. Endeavour.

Remarks
Baker (1980) reported this species as a synonym of *Astrobrachion adhaerens* (Studer, 1884). Although H.L. Clark (1938) indicates there are two specimens with the number WAM 4926, only the holotype is in the collection. The paratype is in the MCZ collections, MCZ#3668 (Baker, 1980).

Family Euryalidae Gray, 1840

**Genus Euryale Oken, 1815**

*euryale euopla* H.L. Clark, 1938

(Junior synonym of *Euryale aspera* Lamarck, 1816)

*euryale euopla* H.L. Clark, 1938: 203–204, plate 23, figure 1.

Material Examined

Holotype number WAM 9683 (1; dry) [new registration number: WAM Z 1954].
Locality: Bald Island [34°55'S, 118°27'E], E of Albany, Western Australia, collected by the Chief Inspector of Fisheries.

Remarks
Baker (1980) reported this species as a synonym of *Euryale aspera* Lamarck, 1816. Some of the arms of the specimen are damaged.

Family Gorgonocephalidae Ljungman, 1867

**Genus Asteroporpa Oersted and Lütken, 1856**

Subgenus *Asteroporpa* (*Astromoana*) Baker, 1980

*asteroporpa* (*Astromoana*) indicus Baker, 1980


Material Examined

Holotype number WAM 7857-75 (1; dry) [new registration number: WAM Z 1955].
Locality: CSIRO station DM6/63/182, W of Point Cloates (23°05'S, 113°23'E), Western Australia, beam trawl at 77 fathoms [141 m] depth, 7 October 1963, collector unknown.

Remarks
H.L. Clark (1914) notes there are two specimens with the number WAM 4921, the larger of which is the holotype. Only one specimen remains in the collection, the other is in the MCZ Dry Collection (MCZ#3670) and is labelled paratype. Baker (1980) transferred this species to the genus *Astrosierra* Baker, 1980.
consisted of ten specimens with the WAM number 4924. Rowe and Gates (1995) reported that the WAM has ten syntypes. The holotype is labelled as such on the original label in H.L. Clark's handwriting and a total of six specimens are held in the WAM; the holotype and five paratypes. Three paratypes are in the MCZ Wet Collection (MCZ#3683) and two are in the Dry Collection (MCZ#3667) (F. J. Collier, personal communication) bringing the total number in the type series to 11. We have no explanation regarding the additional specimen in the type series.

**Order OPHIURIDA Müller and Troschel, 1840**

**Family Amphiuridae Ljungman, 1867**

**Genus Amphiopus Verrill, 1899**

**Subgenus Amphiopus (Amphiopus) Verrill, 1899**

*Amphiopus stenaspis* H.L. Clark, 1938


**Material Examined**

*Paratype number WAM 198-39 (1; dry) [new registration number: WAM Z 1946].

Locality: 3'/^ mile reef. Port Darwin [12°27'S, 130°48'E], Northern Territory, on rock, a little below low water mark [0-1 m depth], June 24 1929, H.L. Clark, CAH Expedition.

**Remarks**

This specimen is one of eight paratypes collected from the same rock fragment. A.M. Clark (1970) placed this species in the subgenus *Amphiopus (Amphiopus) Verrill, 1899*. Rowe and Gates (1995) do not mention that a paratype of this species is in the WAM.

**Genus Amphiura Forbes, 1843**

**Subgenus Amphiura (Amphiura) Forbes, 1843**

*Amphiura bidentata* H.L. Clark, 1938


**Material Examined**

*Paratype number WAM 190-39 (1; dry) [new registration number: WAM Z 1947].

Locality: Broome [17°58'S, 122°14'E], Western Australia, mud flats near jetty, September 1929, H.L. Clark, CAH Expedition.

**Remarks**

Baker (1979) synonymised this species with *Amphiura (Amphiura) catephes* H.L. Clark, 1938. Rowe and Gates (1995) do not mention that a paratype of *A. phrixa* is held in the WAM.

**Genus Ophionephthys Lütken, 1869**

*Ophionephthys tenuis* H.L. Clark, 1938

(Currently *Ophiopeltis* tenuis (H.L. Clark, 1938))


**Material Examined**

*Paratypes number WAM 193-39 (2; dry) [new registration number: WAM Z 1950].

Locality: Roebuck Bay, Broome [18°04'S, 122°19'E], Western Australia, mud flats near jetty, September 1929, CAH Expedition.

**Remarks**

This species was transferred to *Amphiura (Ophiopeltis) tenuis* (H.L. Clark, 1938) by A.M. Clark (1970). Rowe and Gates (1995) do not mention that
paratype material of this species is in the WAM. Both specimens have some damaged arms.

Family Ophiacanthidae Perrier, 1891
Genus Ophiacantha Müller and Troschel, 1842

Ophiacantha clavigera Koehler, 1907

Material Examined
Paralectotype number WAM 4416 (1; wet) [new registration number: WAM Z 1958].
Locality: Station 56, Koombana Bay [33°18'S, 115°39'E], SW of Bunbury, Western Australia, 14.5–18 m depth, 28 June 1905, W. Michaelsen and R. Hartmeyer, Hamburg SW Australian Expedition.

Remarks
Baker and Devaney (1981) noted that three museums (MNB, ZMH and WAM) have specimens labelled holotype, or type, from station 51 (Cockburn Sound) and station 56 (Koombana Bay). They selected Cockburn Sound as the type locality and designated ZMH E2016 from station 51 as lectotype. The remaining specimens in the type series were designated paralectotypes.

Ophiacantha shepherdii Baker and Devaney, 1981

Material Examined
Paralectotypes number WAM 19-81 (1; dry) [new registration number: WAM Z 1959].
Locality: Oedipus Point, West Island [32°31'S, 133°15'E], South Australia, 15 m depth, S.A. Shepherd.

Remarks
Rowe and Gates (1995) did not record that paratypes are held in the WAM. These specimens are presently missing from the collection.

Family Ophiactidae Matsumoto, 1915
Genus Ophiactis Lütken, 1856

Ophiactis acosneta H.L. Clark, 1938
(junior synonym of Ophiactis macrolepidota Marktanner-Turneretscher, 1887)

Material Examined
Paralectotype number WAM 216-39 (1; dry) [new registration number: WAM Z 1960].
Locality: Broome [17°58'S, 122°14'E], Western Australia, 5–8 fathoms [9–15 m] depth, 26 October 1929, H.L. Clark.

Remarks
Rowe and Gates (1995) did not report that three paratypes of this species are held in the WAM. One specimen has a few arms detached.

Ophiactis fuscocolinata H.L. Clark, 1938

Material Examined
Paralectotypes number WAM 218-39 (1; dry) [new registration number: WAM Z 1962]; WAM 219-39 (1; dry) [new registration number: WAM Z 1963]; WAM 220-39 (1; dry) [new registration number: WAM Z 1964].
Locality: East Point [12°25'S, 130°49'E], Darwin, Northern Territory, June and July 1929, H.L. Clark and A.A. Livingstone, CAH Expedition.

Remarks
Rowe and Gates (1995) did not report that three paratypes of this species are held in the WAM. One specimen has a few arms detached.

Ophiactis laevis H.L. Clark, 1938
(junior synonym of Ophiactis tricolor H.L. Clark 1938)

Material Examined
Paralectotypes number WAM 221-39 (1; dry) [new registration number: WAM Z 1965]; WAM 222-39 (1; dry) [new registration number: WAM Z 1966].
Locality: Koombana Bay, Bunbury [33°18'S, 115°39'E], Western Australia, 5–8 fathoms [9–15 m] depth, 26 October 1929, H.L. Clark.

Remarks
Baker and Devaney (1981) reported this species as a synonym of Ophiactis tricolor H.L. Clark, 1938. Rowe and Gates (1995) did not report that paratypes of this species are held in the WAM. The specimens are damaged; one has most of the arms detached.
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Material Examined
Paratypes number WAM 270-39 (1; dry) [new registration number: WAM Z 1967]; WAM 271-39 (1; dry) [new registration number: WAM Z 1968].
Locality: Cape Peron [32°16'S, 115°41'E], Western Australia, October 1929, H.L. Clark and E.W. Bennett.

Remarks
H.L. Clark (1938) states the locality as Point Peron in error. Rowe and Gates (1995) did not report that these paratypes are held in the WAM. Some arms of these specimens are broken at the tips.

Genus Ophiomastix Müller and Troschel, 1842

Ophiomastix stenozonula Devaney, 1974


Material Examined
Paratype number WAM 149-72 (1; dry) [new registration number: WAM Z 1969].

Remarks
Three of the arms of this specimen are damaged.

Family Ophiodermatidae Ljungman, 1867

Genus Ophiarachnella Ljungman, 1872

Ophiarachnella ramsayi (Bell, 1888)

Ophiarachnella ramsayi variety pulchra H.L. Clark, 1938

Ophiarachnella ramsayi variety pulchra H.L. Clark, 1938: 347–349, plate 14, figure 1.

Material Examined
Holotype number WAM 15058 (1; dry) [new registration number: WAM Z 1970].
Locality: Rottnest Island [32°01'S, 115°30'E], Western Australia, January 1929, Mr. Horbury.

Remarks
This specimen is the holotype of the variety. Rowe and Gates (1995) do not mention the variety pulchra.

Genus Ophiopoeza Peters, 1851

Ophiopoeza kingi Devaney, 1974


Material Examined
Paratypes number WAM 148-72 (2; dry) [new registration number: WAM Z 1971].

Family Ophionereididae Ljungman, 1867

Genus Ophionereis Lütken, 1859

Ophionereis stigma H.L. Clark 1938 (junior synonym of Ophionereis dubia (Müller and Troschel, 1842))


Material Examined
Paratype number WAM 262-39 (1; dry) [new registration number: WAM Z 1974].
Locality: Broome [17°58'S, 122°14'E], Western Australia, August and September, 1929, CAH Expedition.

Remarks
H.L. Clark (1938) did not designate paratypes but the specimen is labelled paratype on the original label in H.L. Clark's handwriting. A.M. Clark (1953) reported this species as a synonym of Ophionereis dubia (Müller and Troschel, 1842). Rowe and Gates (1995) did not record that one paratype of this species is held in the WAM. They record the type locality as Cape Leveque which is north of Broome. The arms and disc have separated.

Family Ophiotrichidae Ljungman, 1866

Genus Lissophiothrix H.L. Clark, 1938

Lissophiothrix delicata H.L. Clark, 1938


Material Examined
Paratype number WAM 239-39 (1; dry) [new registration number: WAM Z 1975].

Remarks
Rowe and Gates (1995) did not record that one paratype of this species is held in the WAM. Two arms are detached from the specimen.
Genus *Macrophiothrix* H.L. Clark, 1938

*Macrophiothrix scotia* H.L. Clark, 1938  
(junior synonym of *Macrophiothrix megalopoma* H.L. Clark, 1938)

*Macrophiothrix scotia* H.L. Clark, 1938: 300-302, plate 24, figure 2.

**Material Examined**

*Paratype* number WAM 243-39 (1; dry) [new registration number: WAM Z 1976].

Locality: Entrance Point [18°0°F, 122°13'E], Broome, Western Australia, August and September 1929, H.L. Clark.

**Remarks**

Hoggett (1991) reported this species as a synonym of *Macrophiothrix megalopoma* H.L. Clark, 1938. Rowe and Gates (1995) did not record that a paratype of *Macrophiothrix scotia* is held in the WAM.

*Macrophiothrix spinifera* H.L. Clark, 1938  
(junior synonym of *Macrophiothrix megalopoma* H.L. Clark, 1938)


**Material Examined**

*Paratype* number WAM 244-39 (1; dry) [new registration number: WAM Z 1980].

Locality: Broome [17°58'F, 122°14'E], Western Australia, August and September 1929, H.L. Clark, CAH Expedition.

**Remarks**

Hoggett (1991) reported this species as a synonym of *Macrophiothrix megalopoma* H.L. Clark, 1938. Rowe and Gates (1995) did not record that a paratype of *Macrophiothrix spinifera* is held in the WAM. Some of the tips of the arms of the specimen are damaged.

*Ophiothrix stelligera* H.L. Clark, 1938  
(junior synonym of *Ophiothrix (Ophiothrix) ciliaris* Lamarck, 1816)

*Ophiothrix stelligera* H.L. Clark, 1938: 274.

**Material Examined**

*Paratype* number WAM 237-39 (1; dry) [new registration number: WAM Z 1978].

Locality: Broome [17°58'F, 122°14'E], Western Australia, June 1932, H.L. Clark.  
*Paratype* number WAM 238-39 (1; dry) [new registration number: WAM Z 1980].

Locality: Broome [17°58'F, 122°14'E], Western Australia, June 1932, H.L. Clark.

**Remarks**

Rowe and Gates (1995) reported *Ophiothrix stelligera* as a synonym of *Ophiothrix (Ophiothrix) ciliaris* (Lamarck, 1816). They did not mention the form *atra* described by H.L. Clark (1938). This material is the paratype of the form *atra*.

*Ophiothrix stelligera* form *atrolineata* H.L. Clark, 1938  
(junior synonym of *Ophiothrix (Ophiothrix) ciliaris* Lamarck, 1816)

*Ophiothrix stelligera* form *atrolineata* H.L. Clark, 1938: 274.

**Material Examined**

*Paratype* number WAM 4209 (1; wet) [new registration number: WAM Z 1981].

Locality: Station 26, Sunday Island, Shark Bay [26°07'F, 113°14'E], Western Australia, 5.5 m depth, 17 June 1905, W. Michaelson and K. Hartmeyer, Hamburg SW Australian Expedition.

**Remarks**

H.L. Clark (1946) reported this species as a synonym of *Ophiothrix (Ophiothrix) caespitosa* Lyman, 1879. Rowe and Gates (1995) did not record this paratype in the WAM.

**Subgenus Ophiothrix (Placophiothrix)**

*Ophiothrix hartmeyeri* Koehler, 1907  
(junior synonym of *Ophiothrix (Ophiothrix) caespitosa* Lyman, 1879)


**Material Examined**

*Paratype* number WAM 4209 (1; wet) [new registration number: WAM Z 1981].

Locality: Station 26, Sunday Island, Shark Bay [26°07'F, 113°14'E], Western Australia, 5.5 m depth, 17 June 1905, W. Michaelson and K. Hartmeyer, Hamburg SW Australian Expedition.

**Remarks**

H.L. Clark (1946) reported this species as a synonym of *Ophiothrix (Ophiothrix) caespitosa* Lyman, 1879. Rowe and Gates (1995) did not record this paratype in the WAM.

Subgenus *Ophiothrix (Placophiothrix)*

*Ophiothrix (Placophiothrix) westwardii*  
Devaney, 1974
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(junior synonym of Macrophiothrix propinquua (Lyman, 1861))

Ophiothrix (Placophiothrix) westwardi Devaney, 1974: 143–149, figures 8–14.

Material Examined
Paratype number WAM 150-72 (1; dry) [new registration number: WAM Z 1982].

Paratypes number WAM 151-72 (2; dry) [new registration number: WAM Z 1983].

Paratype number WAM 152-72 (1; dry) [new registration number: WAM Z 1984].
Locality: Station THI, haul 1, Tahuata Island, Marquesas Islands, S Pacific, (10°00'S, 139°10'W), dredged on coarse yellow sand, 45—46 fathoms, [82–84 m] depth, 28 September 1967, D.M. Devaney and T. Richer! on Pele.

Paratype number WAM 153-72 (1; wet) [new registration number: WAM Z 1985].

Remarks
Hoggett (1991) recorded this species as a synonym of Macrophiothrix propinquua (Lyman, 1861). Rowe and Gates (1995) did not record these paratypes in the WAM. Some of the specimens are missing some arms.

Family Ophiuridae Lyman, 1865
Genus Ophiolepis Müller and Troschel, 1840
Ophiolepis plateia Ziesenhenne, 1940

Ophiolepis plateia Ziesenhenne, 1940: 41, plate 8, figures 4–6.

Material Examined
Paratypes number WAM 59-73 (2; dry) [new registration number: WAM Z 1986].

Remarks
H.L. Clark (1914) described the holotype as "one of the largest and most perfectly preserved cidarids I have ever seen". Unfortunately the specimen has deteriorated and now consists of disarticulated plates and spines. Originally there were two specimens with this number in the WAM but a specimen labelled cotype (syntype) is in the MCZ Dry Collection (MCZ#3900) (F.J. Collier, personal communication), and should be regarded as a paratype (ICZN 1985 Recommendation 73D).

Order DIADEMATOIDA Duncan, 1889
Family Diadematidae Gray, 1855
Genus Centrostephanus Peters, 1854
Centrostephanus tenuispinus H.L. Clark, 1914


Material Examined
Holotype number WAM 4936 (1; dry) [new registration number: WAM Z 1878].
Locality: Between Fremantle [32°03'S, 115°45'E] and Geraldton [28°46'S, 114°37'E], Western Australia, trawled, date and collector unknown on F.I.S. Endeavour.

Remarks
H.L. Clark (1914) described the holotype as "one of the largest and most perfectly preserved cidarids I have ever seen". Unfortunately the specimen has deteriorated and now consists of disarticulated plates and spines. Originally there were two specimens with this number in the WAM but a specimen labelled cotype (syntype) is in the MCZ Dry Collection (MCZ#3900) (F.J. Collier, personal communication), and should be regarded as a paratype (ICZN 1985 Recommendation 73D).

Order CIDAROIDA Claus, 1880
Family Cidaridae Gray, 1825
Genus Phyllacanthus Brandt, 1835
Phyllacanthus magnificus H.L. Clark, 1914


Material Examined
Holotype number WAM 4935 (1; dry) [new registration number: WAM Z 1715].
Locality: Between Fremantle [32°03'S, 115°45'E] and Geraldton [28°46'S, 114°37'E], Western Australia, trawled, date and collector unknown on F.I.S. Endeavour.

Remarks
H.L. Clark (1914) described the holotype as "one of the largest and most perfectly preserved cidarids I have ever seen". Unfortunately the specimen has deteriorated and now consists of disarticulated plates and spines. Originally there were two specimens with this number in the WAM but a specimen labelled cotype (syntype) is in the MCZ Dry Collection (MCZ#3900) (F.J. Collier, personal communication), and should be regarded as a paratype (ICZN 1985 Recommendation 73D).
**Paratypes** number WAM 4936 (1; dry) [new registration number: WAM Z 1879]; WAM 4936 (1; dry) [new registration number: WAM Z 1715].
Locality: Between Fremantle [32°03'S, 115°45'E] and Geraldton [28°46'S, 114°37'E], Western Australia, June 1912, W.B. Alexander on F.I.S. Endeavour.

**Remarks**
H.L. Clark (1914) records the presence of two specimens with the number WAM 4936, one of which, recorded as such on the original label, is the holotype. A total of three specimens with the number 4936 are held in the collection and two are labelled cotype by H.L. Clark, but should be regarded as paratypes (ICZN 1985 Recommendation 73D). Rowe and Gates (1995) do not mention that paratype material is held in the WAM in addition to the holotype, and query that a paratype specimen is held in the MCZ. The MCZ does hold an additional specimen (MCZ#3905) as a dry paratype collected from between Fremantle and Geraldton.

**Order TEMNOPLEUROIDA** Mortensen, 1942
**Family** Temnopleuridae A. Agassiz, 1872
**Genus** *Psctidechinius* Mortensen, 1903
*Psctidechinius flemingi* Fell, 1958: 36, plate 3A, C, plate 5A.

**Material Examined**
Paratype number WAM 1751-75 (1; dry) [new registration number: WAM Z 1888].
Locality: Station 41, Chatham Island Rise [42°50'-44°00'S, 174°00'-178°00'E], New Zealand, 260 fathoms [475 m] depth, January 1954, Chatham Island Expedition.

**Remarks**
This specimen was presented to the WAM by A.N. Baker of the National Museum of New Zealand. The specimen is a juvenile.

**Order CLYPEASTEROIDA** A. Agassiz, 1872
**Family** Clypeasteridae L. Agassiz, 1835
**Genus** *Clypeaster* Lamarck, 1801
Subgenus *Clypeaster* (Coronanthus) Lampert, 1913
*Clypeaster telunis* H.L. Clark, 1914
*Clypeaster telunis* H.L. Clark, 1914: 166-167, plate 23.

**Material Examined**
Holotype number WAM 4937 (1; dry) [new registration number: WAM Z 1877].
Locality: Between Fremantle [32°03'S, 115°45'E] and Geraldton [28°46'S, 114°37'E], Western Australia, June 1912, W.B. Alexander on F.I.S. Endeavour.

**Remarks**
Rowe and Gates (1995) included this species in the subgenus *Clypeaster* (Coronanthus) Lampert, 1913.

**Family Fibulariidae** Gray, 1855
**Genus** *Echinocyamus* Phelsum, 1774
*Echinocyamus planissimus* H.L. Clark, 1938

**Material Examined**
Paratype number WAM 174-39 (1; dry) [new registration number: WAM Z 1880].
Locality: Broome [17°58'S, 122°14'E], Western Australia, September 1929, H.L. Clark, CAH Expedition.

**Remarks**
Although H.L. Clark (1938) did not designate paratypes the original label is marked paratype. Rowe and Gates (1995) do not mention that paratype material of this species is in the WAM.

**Family Laganidae** A. Agassiz, 1873
**Genus** *Peronella* Gray, 1855
*Peronella aphnostina* H.L. Clark, 1914 (junior synonym of *Peronella lesueuri* (Valenciennes, 1841))

**Material Examined**
Holotype number WAM 3936 (1; dry) [new registration number: WAM Z 1881].
Locality: Carnac Island [32°07'S, 115°40'E], near Fremantle, Western Australia.

**Remarks**
Mortensen (1918) reported this species as a synonym of *Peronella lesueuri* (Valenciennes, 1841). The synonymy of *P. aphnostina* with *P. lesueuri* is not recorded in Rowe and Gates (1995). This specimen has been missing from the collection for a number of years.

**Order SPATANGOIDA** Claus, 1876
**Family** Brissidae Gray, 1855
Locality: Between Fremaunle [32°03'S, 115°45'E] and Geraldton [28°46'S, 114°37'E], Western Australia, June 1912, W.B. Alexander on F.I.S. Endeavour.

**Remarks**
Rowe and Gates (1995) included this species in the subgenus *Clypeaster* (Coronanthus) Lampert, 1913.
Genus *Cyclaster* Cotteau, 1856

*Cyclaster regalis* Baker, 1969


**Material Examined**

*Paratype* number WAM 1754-75 (1; dry) [new registration number: WAM Z1889].

*Locality*: off Coromandel Peninsula, between Mayor and Cuvier Islands (37°08’S, 176°18’E), New Zealand, 210–480 m depth, 1 to 9 January 1969, R.D. Cooper.

**Remarks**

This specimen was presented to the WAM by A.N. Baker of the National Museum of New Zealand.

Genus *Rhynobrissus* A. Agassiz, 1872

*Rhynobrissus tumulus* McNamara, 1982


**Material Examined**

*Holotype* number WAM 1047-81 (1; dry) [new registration number: WAM Z 1871].

*Paratypes* number WAM 1048-81 (1; dry) [new registration number: WAM Z 1872]; WAM 1049-81 (1; dry) [new registration number: WAM Z 1873]; WAM 1050-81 (1; dry) [new registration number: WAM Z 1874]; WAM 1051-81 (11; dry) [new registration number: WAM Z 1875].


**Remarks**

A small piece has broken off WAM 1050-81. The paratype WAM 1048-81 is presently missing from the collection.

Family *Pericosmidae* Lambert, 1905

Genus *Pericosmus* L. Agassiz, 1847

*Pericosmus porphyrocardius* McNamara, 1984

*Pericosmus porphyrocardius* McNamara, 1984: 89–95, figures 1–3.

**Material Examined**

*Holotype* number WAM 729-83 (1; dry) [new registration number: WAM Z 1882].

*Paratypes* number WAM 730-83 (6; dry) [new registration number: WAM Z 1883]; WAM 731-83 (1; dry) [new registration number: WAM Z 1884]; WAM 732-83 (1; dry) [new registration number: WAM Z 1885].

*Locality*: Station SO 2/82/17A, 140 nautical miles NNW of Port Hedland, (18°01’S, 118°06’E to 18°04’S, 118°12’E), Western Australia, trawled from foraminiferal mud at 410–420 m depth, 3 April 1982, L.M. Marsh on R.V. *Soela*.

*Paratype* number WAM 733-83 (1; dry) [new registration number: WAM Z 1886].

*Locality*: Station SO 2/82/38, 122 nautical miles NNW of Port Hedland, (18°22’S, 117°56’E to 18°23’S, 117°54’E), Western Australia, Engel trawled for 30 minutes from mud at 316–309 m depth, 11 April 1982, L.M. Marsh on R.V. *Soela*.

*Paratypes* number WAM 734-83 (4; dry) [new registration number: WAM Z 1887].

*Locality*: Station SO 4A/82/8D, 150 nautical miles NNW of Port Hedland, (17°58’S, 118°25’E), Western Australia, trawled from mud at 376 m depth, 1 August 1982, J. Fromont on R.V. *Soela*.

**Remarks**

McNamara (1984) reported that there were six specimens with the number WAM 730-83 but only five remain. The specimens WAM 731-83, 732-83 and 733-83 are all slightly damaged.

Class *HOLOTHUROIDEA* de Blainville, 1834

Order *DENDROCHIROTIDA* Brandt, 1835

Family *Cucumariidae* Ludwig, 1875

Genus *Actinocucumis* Ludwig, 1875

*Actinocucumis longipedes* H.L. Clark, 1938

*Actinocucumis longipedes* H.L. Clark, 1938: 480–81, figure 45.

**Material Examined**

*Paratype* number WAM 4-64 (1; wet) [new registration number: WAM Z 1892].


**Remarks**

Heding and Panning (1954) reported this species as a synonym of *Actinocucumis typica* Ludwig, 1875. Rowe and Gates (1995) do not mention that paratype material of *A. longipedes* is held in the WAM. They record the type locality as False Cape Bossut, WA.

Genus *Colochiriis* Troschel, 1846

*Colochiriis axiologus* H.L. Clark, 1914
L.M. Marsh, J. Fromont, M. Salotti


Material Examined

Holotype number WAM 4033 (1; wet) [new registration number: WAM Z 1893].
Locality: Port Hedland [20°18'S, 118°35'E], Western Australia, B.E. Bardwell.

Remarks
H.L. Clark (1914) reported the paratype number as 4032, but this number is not an echinoderm in the WAM catalogue. The MCZ has a specimen labelled syntype (MCZ#940) (F.J. Collier, personal communication), so we suggest the number 4032 for a specimen of this species was an error. The MCZ material should be regarded as a paratype (ICZN 1985 Recommendation 73D). Rowe and Gates (1995) report that the holotype and paratype of Colochirus axiologus are both held in the WAM. Cherbonnier (1988) reported this species as a synonym of Pseudocolochirus violacetis (Théel, 1886).

Genus Leptopentacta H.L. Clark, 1938

Leptopentacta grisea H.L. Clark, 1938

Material Examined
Paratype number WAM 2-64 (1; wet) [new registration number: WAM Z 1895].
Locality: Broome [17°58'S, 122°14'E], Western Australia, mudflat near jetty, August 1929, H.L. Clark.

Remarks
Rowe and Gates (1995) do not mention that paratype material of this species is in the WAM.

Genus Loisettea Rowe and Pawson, 1985

Loisettea amphicteua Rowe and Pawson, 1985
Loisettea amphicteua Rowe and Pawson, 1985: 672–677, figures 1–3.

Material Examined
Paratype number WAM 54-63 (1; wet) [new registration number: WAM Z 1896].
Locality: 3 to 4 nautical miles E of Delambre Island [20°26'S, 117°04'E], Dampier Archipelago, Western Australia, dredged at 10 fathoms [18 m] depth, rocky, 5 June 1960, B.R. Wilson on Davosia.
Paratype number WAM 676-82 (1; wet) [new registration number: WAM Z 1900].
Locality: Station SO 1/255, 36 nautical miles N of Port Walcott, Western Australia (20°08'E), trawled on silty sand at 50 m depth, L.M. Marsh on R.V. Soela.

Remarks

Family Phyllophoridae Oestergren, 1907

Genus Thyone Oken, 1815

Thyone grisea H.L. Clark, 1938
Thyone grisea H.L. Clark, 1938: 467–468, figure 40.

Material Examined
Paratype number WAM Z 1907 (1; wet).
Locality: False Cape Bossut S to 80 Mile Beach [18°35'S, 121°44'E], Western Australia, 8 September 1929, H.L. Clark.

Remarks
This specimen was not registered until 1998. Two labels are with this specimen. The label written by H.L. Clark's assistant designates the material as paratype. A later label (the writing on which we do not recognise) notes the material as probably metatype. We select the designation given by the earliest author.

Thyone minuta H.L. Clark, 1938
(currently Stolus minuta (H.L. Clark, 1938), possibly a junior synonym of Stolus conjungens (Semper, 1868))

Thyone minuta H.L. Clark, 1938: 470–471, figure 42.
Catalogue of Recent echinoderm types

Material Examined

\textit{Paratype} number WAM 1-64 (6; wet) [new registration number: WAM Z 1908].

Locality: Pearl Shoal, Broome \[18°00'S, 122°09'E\], Western Australia, 5-7 fathoms \[9-13 m\] depth, June 1932, H.L. Clark.

Remarks

Rowe in Rowe and Gates (1995) transferred this species to the genus \textit{Stolus} Selenka, 1867, and suggested that this species may prove to be synonymous with \textit{S. conjungens} (Semper, 1868) but this decision awaits more material. Rowe and Gates (1995) did not mention that paratype material of \textit{T. minuta} is held in the WAM.

Order ASPIDOCHIROTIDA Brandt, 1835

Family Holothuriidae Ludwig, 1894

\textbf{Genus Holothuria} Linnaeus, 1767

\textit{Holothuria macrop-criona} H.L. Clark, 1938

\begin{itemize}
  \item Possibly a junior synonym of \textit{Holothuria (Thymiosycia) hartmeyeri} Erwe, 1913
\end{itemize}


Material Examined

\textit{Paratypes} number WAM 16469 (1; wet) [new registration number: WAM Z 1902]; WAM 16470 (1; wet) [new registration number: WAM Z 1903]; WAM 16471 (1; wet) [new registration number: WAM Z 1904]; WAM 16472 (1; wet) [new registration number: WAM Z 1905]; WAM 16473 (1; wet) [new registration number: WAM Z 1906]; WAM Z 1961 (1; wet).

Locality: Bathurst Point [32°00'S, 115°33'E], Rottnest Island, Western Australia, December 1929, L. Glauert.

Remarks

H.L. Clark (1938) reports the collection month as October, not December. Marsh and Pawson (1993) recognise \textit{Holothuria macrop-criona} as a species distinct from \textit{H. (Thymiosycia) hartmeyeri} Erwe, 1913. However Rowe and Gates (1995) report that the holotype and probable paratype are both held in the WAM, however a single specimen, labelled holotype on the original label is in the collection.

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Late Cretaceous brachiopods of the Perth and Carnarvon Basins, Western Australia

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Abstract - Late Cretaceous deposits outcrop in the Perth and Carnarvon Basins in Western Australia. Brachiopods occur in the Gingin Chalk in the Perth Basin and in the Toolonga Calcilutite, Korojon Calcarenite and Miria Formation in the Carnarvon Basin. Fifteen species of brachiopods are described or revised from the Santonian to Campanian Gingin Chalk, seven species from the Santonian to Campanian Toolonga Calcilutite, two species from the Campanian to Maastrichtian Korojon Calcarenite and five species from the Late Maastrichtian Miria Formation.

Ten new species are described: EohemitliRris miriaensis sp. nov., E. wildei sp. nov., Protegulorlinpicliia bevanorum sp. nov., Tegulorlinchia brodelberti sp. nov., Terebratulina kendricki sp. nov., Liothyrella brinnellae sp. nov., L. archboldi sp. nov., Commarcula doddiae sp. nov., Zenobiathyris mutabilis sp. nov. and Z. plicatilis sp. nov. This is the earliest record of Liothyrella, and the first record from Australia. A new family, Zenobiathyridae, is proposed.

The presence of a number of genera common to Late Cretaceous and "early Tertiary" of the deposits Antarctic Peninsula suggests that there was a continuous shelf between Western Australia and Antarctica during this period. It is proposed that these brachiopods form part of a high latitude southern circum-Indo-Atlantic faunal province which existed during the Late Cretaceous to the early Cenozoic.

INTRODUCTION

The brachiopod fauna described in this paper was collected from deposits in the Perth Basin and the Carnarvon Basin. Four terebratulids were previously described by Etheridge (1913) as Terebratulina ovata, Magas nicsembrinus, Trigonosennis acanthodes and Magasella cretacea. Three of these were redescribed by Elliot (1952) as Inopinatarcida acanthodes, Kingena mesembrina and Bouchardiella cretacea. Feldtmann (1963) mentioned l. acanthodes, B. cretacea, K. mesembrina, two rhynchoellids and two Terebratulina species. McNamara et al. (1993) also referred to the rhynchoellid and reassigned Terebratulina ovata as Gisilina.

Four Late Cretaceous sequences have yielded brachiopods. These are the Gingin Chalk from the Perth Basin and the Toolonga Calcilutite, Korojon Calcarenite and Miria Formation, all from the Carnarvon Basin.

The Gingin Chalk of the Perth Basin (Figure 1), was described as a unit which consists of white chalky limestone with glauconite and beds of greensand in some areas (Glauert 1910). It rests disconformably on the Dandaragan Sandstone or conformably on the Molecap Greensand. The Poison Hill Greensand conformably overlies the Gingin Chalk. The chalk is exposed between Badgingarra in the north and Gingin in the south. It is richly fossiliferous containing regular echinoids, bivalves, gastropods, serpulid worms, ammonites, crinoids, ostracods, foraminifers and coccoliths.

The Toolonga Chalk from the Carnarvon Basin (Figure 2) was described as "a yellow-white, massive, usually rather coherent rock" which contains a base of phosphatic nodules and chert nodules present in the upper half (Clarke and Teichert 1948). It was named after Toolonga Hill, the highest part of the scarp north-west of the Murchison River. The chalk is widely distributed throughout the lower Murchison River area. Renamed the Toolonga Calcilutite, it was described as "a unit of pale-grey to light-green calcilutite with some chalk in the lower part" (Johnston et al. 1958). It is overlain conformably by the Korojon Calcarenite or disconformably by Tertiary deposits. In turn, it overlies disconformably the Alinga Formation. Fossils determined by Clarke and Teichert (1948) include echinoid spines, crinoids, serpulid worms, belemnite fragments, numerous bivalves, brachiopods and abundant foraminifers.
The Late Maastrichtian Miria Formation (Figure 3) of the Carnarvon Basin, Western Australia contains a rich fauna of invertebrates. This includes ammonoids described by Henderson and McNamara (1985) and Henderson et al. (1992). Bivalves, gastropods and scaphopods have also been described (Darragh and Kendrick 1991, Darragh and Kendrick 1994). McNamara (1987) described a holasteriod echinoid from the same formation. The Miria Formation also contains nannofossils described by Shafik (1990). A possible theropod humerus (Long 1992) and an incomplete ulna from a large pterodactyloid pterosaur (Bennett and Long 1991) have also been described. Corals and bryozoans remain undescribed. This paper describes the brachiopod fauna and discusses its palaeogeographical significance.

The Miria Formation consists of cream coloured calcarenite 0.6–2.1 m thick extending some 80 km in the Giralia Range, south of Exmouth Gulf. It overlies disconformably the Campanian-Early Maastrichtian Korojon Calcarenite (Darragh and Kendrick 1991) and is in turn succeeded disconformably by the Paleocene Boongerooda Greensand, of the Cardabia Formation (Henderson and McNamara 1985). The formation has been exposed by extensive gully erosion (Henderson et al. 1992).

According to Darragh and Kendrick (1994), the Miria assemblage is consistent with both Tethyan and Temperate affinities.

MATERIAL AND METHODS

The specimens examined have been collected over the past century by a number of geologists and palaeontologists affiliated with the Geological Survey of Western Australia, the University of Western Australia and the Western Australian Museum. Principal collectors include Brian McGowan, Bob Henderson, Ken McNamara, John Long, Tom Darragh and George Kendrick.

Measurement of specimens was undertaken with digital callipers to an accuracy of 0.1 mm. Length, width and depth measurements of all specimens were recorded. Camera lucida diagrams were then prepared after each grinding. Photographs were taken with a Nikon F 90 X camera with a macro lens and each specimen was prepared with a coating of ammonium chloride for photography.

SYSTEMATIC PALAEOLOGY

Phylum Brachiopoda Dumeril, 1806

Subphylum Rhynchonelliformea Popov, Bassett, Holmer & Laurie, 1993
Figure 2 Late Cretaceous Toolonga Calcilutite (Toolonga Hill, Meanarra Hill and Murchison House Station) and Korojon Calcarenite (Giralia Range) in the Carnarvon Basin.

Order Rhynchonellida Kuhn, 1949
Superfamily Rhynchonelloidea Gray, 1848
Family Basiliolidae Cooper, 1959
Subfamily Basiliolinae Cooper, 1959
Genus *Eohemithyris* Hertlein and Grant, 1944
Type Species *Eohemithyris alexi* Hertlein and Grant, 1944.

*Eohemithyris miriaensis* sp. nov.
Figure 4 A–F

Material Examined

**Holotype**
WAM 96.818, Gully 500 m northwest of West Tank, Giralia Station, Giralia Range, Carnarvon Basin, Miria Formation, Maastrichtian.

**Paratype**
WAM 96.804, Gully 1 km northwest of West Tank, Giralia Station, Giralia Range, Carnarvon Basin, Miria Formation, Maastrichtian.

**Diagnosis**
Two valves equally biconvex; shell smooth; foramen submesothyridid; deltoidal plates conjunct.
Description

Exterior. Small triangular shell up to 11.7 mm long. Biconvex, depth to 59% shell length. Width greatest anterior to mid-length, to 97% shell length. Lateral margin of ventral valve curved in posterior two thirds, dips to form a deep sulcus anteriorly, dorsal valve curved posteriorly, flattens towards anterior commissure like the keel of a boat, widest point one third distance to cardinal margin. Shell smooth; no punctation; not costate; growth lines distinct. Cardinal margin gently curved; lateral margin curves gently towards ventral valve; anterior commissure bisulcate. Umbo short, pointed; beak erect; foramen small (4% shell length), submesothyridid; deltidal plates conjunct.

Internal structures unknown.

Remarks

This species is referred to Loehemithyris as the two valves are equally convex and it lacks costation. Rhytirhynchia Cooper, 1957 and Probolarina Cooper, 1959 are clearly costate. The genus Basilola Dall, 1908 has an inconspicuous fold while that of Loehemithyris is quite distinct. Neohuncha Thomson, 1915 has an undiscernible anterior commissure and Streptaria Cooper, 1959 is sharply uniplicate while this species of Loehemithyris is bisulcate. Loehemithyris miraensis has an bisulcate anterior commissure. E. columnus (Hedley), a Recent species from Gabo Island of the Coast of Victoria, Australia, is uniplicate and costate, the costae creating a crenulate margin, a feature absent in E. miraensis. E. alexi Hertlein and Grant, 1944, an Eocene species from California U.S.A., although smooth shelled, has a uniplicate anterior commissure. F. graji (Woodward, 1855), a Recent species from Fiji Islands, is costate and uniplicate, the costae once again creating crenulate margins. E. gettysburgensis Cooper, 1959, a Miocene species from Gettysburg, Washington, U.S.A., is smooth shelled but has a uniplicate anterior commissure while E. miraensis is bisulcate.

Etymology

The name is derived from the Miria Formation.

Loehemithyris wildei sp. nov.

Material Examined

Holotype

WAM 6705, Hosking' Chalk, Gingin Chalk, Perth Basin, Santonian-Campanian.
Late Cretaceous brachiopods

Paratypes
WAM 70.1833, Gingin; WAM 97.700, McIntyre’s Gully; WAM 78.4356, “Kayanaba”, Dandaragan; Gingin Chalk, Perth Basin, Santonian-Campanian;

Other Material
Gingin Chalk: WAM 3850, WAM 6254, 76.2246 Gingin; WAM 6188, 6444/5, 74.1261, McIntyre’s Gully, Gingin; WAM 6427, 7460/1, Molecap Hill, Gingin; WAM 63.129, 74.1261, 80.743, Yatheroo, Dandaragan; Gingin Chalk, Perth Basin, Santonian-Campanian.

Toolonga Calcilutite: WAM 88.884, Meanarra Hill, Toolonga Calcilutite, Carnarvon Basin, Santonian-Campanian.

Toothoga Calcilutite: WAM 88.884, Meanarra Hill, Toolonga Calcilutite, Carnarvon Basin, Santonian-Campanian.

Diagnosis
Finely costellate to anterior, deeply costellate at commissure, variable, thin outer socket ridge.

Description
Exterior. Small to medium subcircular shell to 11 mm in length. Biconvex, ventral valve less convex, depth 60% shell length. Width greater than length in some specimens, widest at or anterior to mid-length. Growth lines distinct, fine shallow costellation, plications developing anteriorly, especially in larger specimens. Cardinal margin wide to margin, rounded; lateral valve edge bevelled, lateral margin straight, rises to dorsal valve at anterior; anterior commissure uniplicate to sulciplicate to multiplicate. Umbo short, sharp, erect to slightly incurved; beak ridges sharp. Foramen small, 1-2% shell length, oval, submesothyridid; deltidal plates disjunct, palintrope, slightly concave.


Dorsal valve. Outer socket ridge thin; socket small, curved floor. Inner socket ridge curved partially over socket; groove between crural base and inner socket ridge. Loop incomplete. Cardinal process narrow cup above concave small septalium.

Remarks
Eohemithyris miriaensis (Craig, herein), a Maastrichtian species described from the Miria Formation, Carnarvon Basin, Western Australia differs from E. wildei in that the shell is smooth. This is also the case for E. alexi Hertlein and Grant, 1944, an Eocene species from California U.S.A. and E. gettysburgensis Cooper, 1959, a Miocene species from Gettysburg, Washington, U.S.A. Recent species are described as costellate and uniplicate but differ in having a thicker outer socket ridge and the costae being consistently pronounced. This is the earliest known occurrence of the genus.

Etymology
The species is named after Dr S. A. Wilde, Associate Professor of Geology, School of Applied Geology, Curtin University of Technology.

Family Hemithyrididae Rzhonsnitskaya, 1956
Genus Protegnlorhynchia Owen, 1980

Type Species
Protegnlorhynchia meridionalis Owen, 1980.

Revised Diagnosis
Rounded straight costae, not spinose; beak erect to incurved; foramen small hypothyridid; socket floor corrugated; crura short, divergent, radulifer; short median septum; cardinal process indistinct, triangular.

Protegnlorhynchia meridionalis Owen, 1980

Figure 4 M-Q

1980 Protegnlorhynchia meridionalis Owen: 129, figs 15 a-c, 16.

Material Examined
WAM 82.1937 Gingin; WAM WAM 6186, 68.670, McIntyre’s Gully, Gingin; WAM 4527, 6253, Hosking’s Chalk, Gingin; WAM 5937-9, 44; Musk’s Chalk, Gingin; WAM 74.1142, Molecap Hill, Gingin; WAM 63.131, 77.3548/3550, Yatheroo, Dandaragan; WAM 4242, “Kayanaba”, Dandaragan; Gingin Chalk, Perth Basin, Santonian-Campanian.

Description
Exterior. Small to medium sized triangularly pentagonal shell to 11.1 mm in length. Biconvex, ventral valve slightly flatter, depth 61% shell length. Width greatest just anterior to mid-length, 95% shell length. Growth lines distinct to prominent, costellate, ribs as wide as troughs, rounded, 3 ribs per mm at mid length, deep sulcus anterior third of ventral valve. Cardinal margin curved, narrow (60% shell width) to lateral margin; lateral valve edge bevelled, lateral margin sigmoid, dipping strongly towards dorsal valve anterior third of shell, crenulate from cardinal margin; anterior valve edge bevelled, anterior commissure uniplicate, sulcus 64% shell width, crenulate. Umbo sharp, short. Beak erect to incurved; beak ridges sharp. Foramen small, oval, 4% shell length, hypothyridid; deltidal plates obscured as foramen meets dorsal umbo, possibly conjunct. Interarea concave, depressed towards dorsal valve, raised towards foramen.

Interior. Dorsal valve. Outer socket ridge thickened cardinal margin, curves inwards. Socket short, triangular, round floor, striated horizontally. Inner socket ridge curved towards socket, socket
Late Cretaceous brachiopods


Remarks
The specimens have been placed in *Protegulorhynchia meridionalis* Owen, 1980 from the Early Campanian of James Ross Island, Antarctic Peninsula, as they fit the general description and do not fit any other taxon yet described.

*Protegulorhynchia bevanoritni* sp. nov.

Figure 4 R, 5 A–C

Material Examined

Holotype
WAM 6706, Molecap Hill, Gingin Chalk, Perth Basin, Santonian-Campanian.

Paratype
WAM 74.1136, Molecap Hill, Gingin; WAM 4795, One Tree Hill, Gingin; Gingin Chalk, Perth Basin, Santonian-Campanian.

Other Material
WAM 3851, Gingin; WAM 3942, 5289, Molecap Hill, Gingin; Gingin Chalk, Perth Basin, Santonian-Campanian.

Diagnosis
Small *Protegulorhynchia* with numerous costae, parasulcate anterior commissure.

Description
Exterior. Small subpentagonal shell to 6.5 mm in length. Biconvex, both valves equally so, depth 65% shell length. Width just anterior to mid-length, 86% shell length. Growth lines distinct, costellate, non-bifurcating, crowded at umbo, spreading anteriorly, 6 per mm at mid-length, ribs rounded, widening anteriorly, trench widening anteriorly, narrower than ribs posteriorly, wider than ribs anteriorly. Cardinal margin wide, strongly curved; lateral valve edge rounded, lateral margin straight, curved towards ventral valve anteriorly; anterior commissure paraculcate, lateral sulci narrow, central plication wide, 50% shell width, flat. Umbo short, curved; beak erect; beak ridges sharp posteriorly. Foramen circular with spout-like overhanging umbo, hypothryridid; deltidial plates disjunct, raised slightly to form rim.


Remarks
The specimens examined are similar to *Protegulorhynchia meridionalis* Owen, 1980 except for the greater number of costae per mm (6 per mm in *P. bevanoritni* and 3 per mm in *P. meridionalis*) and a parasulcate anterior commissure while the commissure of *P. meridionalis* is uniplicate. These features are of specific importance.

Etymology
The name is in honour of Dr A. W. R. Bevan, Curator of minerals and meteorites at the Western Australian Museum, and his wife Ms J. C. Bevan, Curator of the E. de C. Clarke Geological Museum, University of Western Australia.

Genus *Tegidorhynchia* Chapman and Crespin, 1923

Type Species
*Rhynchonella squamosa* Hutton, 1873.

*Tegidorhynchia hrodelberti* sp. nov.

Figure 5 D–L

Material Examined

Holotype
WAM 74.1300a, Spring Gully, Gingin, Gingin Chalk, Perth Basin, Santonian-Campanian.

Late Cretaceous brachiopods

Paratypes
WAM 74.1300b, c, Spring Gully, Gingin; WAM 70.1836, 76.2221, Gingin; Gingin Chalk, Perth Basin, Santonian-Campanian.

Other Material
Gingin Chalk: WAM 4529, Hosking’s Chalk, Gingin; Gingin Chalk, Perth Basin, Santonian-Campanian.
WAM 74.1264, McIntyre’s Gully, Gingin; WAM 74.1136, Molecap Hill, Gingin; WAM 77.3529, 78.4197, “Kayanaba”, Dandaragan; WAM 74.4396, “Noondel-Wandilla”, Dandaragan; WAM 79.2339, “Kyno”, Dandaragan; Gingin Chalk, Perth Basin, Santonian-Campanian.

Toolonga Chalk: WAM 74.1175, 75.10, Meanarra Hill; WAM 88.220, Murchison House Station; Toolonga Calcutlute, Carnarvon Basin, Santonian-Campanian.

Diagnosis
Small Tegularlynchia, multicostate, wider than long, short pointed umbo, grooved socket teeth, anterior comissure uniplicate.

Description
Exterior. Small, subpentagonal, subtriangular, to subcircular, shell up to 11.5 mm in length. Biconvex, dorsal valve more convex, depth up to 72% shell length. Width greater than length, widest anterior to mid-length, up to 113% shell length. Costellate, 4 ribs per mm at mid-length, bifurcate posterior to mid-length, growth lines distinct, numerous, form rugose pattern with ribs to spinoze. Cardinal margin short, 48% shell length; lateral valve edge rounded, lateral margin straight to gently curved towards ventral valve anteriorly; anterior comissure uniplicate; plication 50% shell width. Umbo strong, pointed; beak erect; beak ridges rounded. Foramen small, up to 6% shell length, round with extension of pedicle collar posteriorly, hypothyridid; deltidal up to 6% shell length, round with extension of plication 50% shell width. Umbo strong, pointed; anterior commissure uniplicate.


Remarks
The costation rate (number per mm) in T. hrodelberti is similar to that of T. boongerooaensis Feacham (1983) in the deeper ‘entral valve and less bulbous ventral valve as well as having a higher ratio of costae (4 per mm in T. hrodelberti and 2.7 per mm in T. ampullacea). T. hrodelberti differs from T. ampullacea Bitner, 1996 in that there is a groove between the inner socket ridge and the crural base, not found in T. hrodelberti. T. boongerooaensis also has a deeper socket than T. hrodelberti. The plication in T. hrodelberti is marked even in the small specimens. McNamara describes the juveniles of T. boongerooaensis as rectimarginate as does Lee (1980) for T. squamosa and T. sublaevis. T. hrodelberti differs from T. ampullacea Bitner, 1996 in the deeper ventral valve and less bulbous ventral valve as well as having a higher ratio of costae (4 per mm in T. hrodelberti and 2.7 per mm in T. ampullacea). T. hrodelberti is now the oldest known occurrence of the genus Tegularlynchia. The species is found in greensand deposits which is consistent with McNamara’s analysis of their substrate preference.

Etymology
Named in honour of my father, Robert (Hrodlebert), from the Saxon meaning famous and bright.
Late Cretaceous brachiopods

Order Terebratulida Waagen, 1883
Suborder Terebratulidina Waagen, 1883
Superfamily Terebratuloidea Gray, 1840
Family Terebratulidae Gray, 1840
Subfamily Terebratulinae Gray, 1840
Genus Liothyrella Thompson, 1916

Type Species
Terebratula uva Broderip, 1883.

Remarks
Cooper (1983) describes the foramen of Liothyrella as submesothyridid whilst Thomson (1927) describes it as epithyridid. Liothyrella archboldi, a species herein described, is clearly permesothyridid. The overall shape of L. archboldi is similar to Dolichozygus Cooper, 1983, but the loop appears to be shorter than that indicated by Cooper for Dolichozygus.

Liothyrella brimmellae sp. nov.

Material Examined
Holotype

Paratypes
WAM 78.948a and b, 92.663, “Kayanaba”, Dandaragan, Gingin Chalk, Perth Basin, Santonian-Campanian.

Diagnosis
Liothyrella with distinct straight radiating ribs, strongly convex valves, relatively long beak.

Description
Exterior. Large ovate shell up to 38 mm in length. Biconvex, depth 57% shell length. Width greatest at mid-length, 74% shell length. Finely densely punctate, growth lines prominent, costellate, 9 ribs per mm at mid-length, distance between ribs variable, bifurcation unclear. Cardinal margin wide, deeply curved, lateral valve edge rounded, lateral margin nearly straight; anterior commissure appears unisulcate to uniplicate. Umbo short, beak suberect, labiate; beak ridges attrite. Foramen large, 6–7% of shell length, mesothyridid, ‘V’ shaped join to deltoidal plates; deltoidal plates conjunct. Symphytium with median ridge, small, concave, triangular, distinct horizontal ribbing.


Dorsal Valve; Outer socket ridge obscured. Inner socket ridge curved partially over socket, fused to crural base and outer hinge plate, form continuous flat, slightly divergent plate. Crural process flatly curved towards lateral margin. Loop incomplete, short, ascending branch rises, widens anteriorly; transverse band most likely arched, wide. No median septum. Thin ridge separates elongated muscle scars. Cardinal process partially obscured, raised cup, narrow rim.

Remarks
There are two specimens, one a mould, the other conjoined. The ribbing is quite distinct. The loop does not appear to be a ring and hence the species is not a Cancellothyris or Terebratulina. Owen (1980) describes Liothyrella lecta from the Campanian of James Ross Island as having “faint radiating ribs”. He mentions it having been first described by Guppy (1866) from Trinidad and later by Buckman (1910) from Antarctica. This new species differs in that the radiating ribs are quite strong, the beak more developed and the valves overall more convex and bulbous. Lithramia Cooper, 1983, another costae short looped genus, has a much shorter truncated beak, non-divergent crura and thin transverse band. Arcuatothyris Popiel-Barczyk, 1972 is also a genus with a short loop and radiating ribs. Liothyrella brimmellae differs from Arcuatothyris in that the ribs are straight while in Arcuatothyris they are curved away from the meridian to the lateral margins.

Etymology
Named after Ms K. Brimmell, Technical Officer at the Western Australian Museum, the collector of both specimens.
Late Cretaceous brachiopods

*Liothyrella archboldi* sp. nov.

Figure 8 D-I, 9 A-B

Material Examined

**Holotype**

WAM 89.1278a Gully 500 m northwest of West Tank, Giralia Station, Giralia Range, Carnarvon Basin, Miria Formation, Maastrichtian.

**Paratypes**

WAM 89.1278 b-g, 96.865 Gully 500 m northwest of West Tank, Giralia Station, Giralia Range, Carnarvon Basin, Miria Formation, Maastrichtian. 74.1267; McIntyre’s Gully, Gingin, Gingin Chalk, Perth Basin, Santonian-Campanian.

Other Material

Gingin Chalk: WAM 4597; 74.1138; 74.1138a, Molecap Hill, Gingin; WAM 8352/3, Gingin; WAM 5413, Musk’s Chalk, Gingin; WAM 1687; McIntyre’s Gully, Gingin; WAM 4576, One Tree Hill, Gingin; WAM 4230/31, Round Hill, “Kayanaba”, Dandaragan; WAM 63.153, “Yatheroo”, Dandaragan; Gingin Chalk, Perth Basin, Santonian-Campanian.

Toolonga Calcitutte: WAM 88.277, Murchison House Station, Toolonga Calcitutte, Carnarvon Basin, Santonian-Campanian.

Korojon Calcarenite: WAM 84.390, Giralia Range, Korojon Calcarenite, Carnarvon Basin, Campanian-Maastrichtian.

Moria Formation: WAM 60.31, 60.61, 65.555, 71.181, 71.242, 71.288, 80.668, 80.694, 80.870, 80.884, 83.2878, 83.2907, 83.2936, 83.2947, 83.2960, 83.3010, 83.3026, 83.3054, 83.3064, 83.3149, 83.3153, 83.3155, 83.3159, 83.3164, 83.390, 84.426, 84.427, 84.428, 84.432, 84.901, 84.908, 84.922, 84.959, 89.1278, 84.1695, 96.748, 96.802, 96.836, 96.839, 96.842, 96.859, 96.863, 96.865, 96.880, 96.888, 96.894-895, 96.909, 96.917, 96.921 Giralia Range, Carnarvon Basin, Miria Formation, Maastrichtian.

Diagnosis

Shell medium-sized, oval to pear shaped; smooth; not depressed; anterior commissure uniplicate. Beak suberect; foramen permesothyridid; symphytium with no median ridge.

Description

**External.** Oval to pear shaped; medium-sized shell, length from 15.7 to 32.8 mm. Biconvex, greatest depth posterior to mid-length, depth 30% of shell length. Maximum width at mid-length or slightly anterior to it; width 60-65% of shell length. Cardinal process strongly curved; lateral valve edge bevelled to rounded to impressed, lateral margin straight until anterior third where it dips strongly toward dorsal valve; anterior commissure uniplicate (fold 30% of shell length). Shell smooth with distinct growth lines; finely and densely punctate. Umbo stout, beak suberect, labiate, beak ridges rounded, beak margins wide, extend to just posterior to mid-line. Foramen large (8% of shell length), round, permesothyridid. Symphytium concaved, small, no median ridge; pedicle collar sessile.

**Internal.** Loop short, elongate, descending branches wide, transverse band arched towards posterior.

Remarks

Some variation exists where the anterior commissure lacks uniplication, remaining rectimarginate as the lateral margin remains straight. One specimen has markings on the shell similar to those caused by pedicle rootlets (Bromley and Surlyk 1973), and there is a great deal of trace fossil activity on the surface of many of the specimens. The majority of the specimens are casts (or internal moulds). Preservation indicates ridging from near the pedicle. These could be calcite ridges or suggestions of the mantle canals.

Allan (1932) described a number of species of *Liothyrella* from the “Tertiary” of New Zealand. *L. concentrica* (Hutton, 1873) from the Late Eocene-Late Oligocene is much more elongate. The beak of *L. gravida* (Suess, 1864) from the Early Miocene is more strongly labiate and the overall shape is more subcircular than in *L. archboldi*. *L. kakaniiensis* (Hutton, 1905) from the Early Oligocene-Miocene is small, inflated, elongate and has an erect beak, distinguishing it from *L. archboldi*. *L. landonensis* Thomson, 1918 from the Middle Oligocene, *L. magna* (Hamilton, 1910) from the Early Oligocene, *L. oamarutica* (Boehm, 1904) from the Late Oligocene-Early Miocene, *L. pulchra* Thomson, 1918.

Figure 7

A-K, *Kingena mesembrina* (Etheridge, 1913). A, C, F, WAM 74.1138a. A, dorsal valve view x 3; C, lateral view x 2.5; F, anterior commissure x 2.5. B, D, E, WAM 74.1138c. B, dorsal valve view x 3; D, lateral view x 2.5; E, anterior commissure x 2.5. G, WAM 78.279a, dorsal valve interior x 5; H, WAM 78.279b, ventral valve interior x 4.5; I, K, WAM 3522. I, lateral view x 5; K, dorsal valve interior x 4.5. J, WAM 74.1138b, ventral valve interior x 3. L-S, *Botichardiella cretacea* (Etheridge, 1913). L, O, P, WAM 74.1301. L, dorsal valve view x 5; O, lateral view x 4.5; P, anterior commissure x 4.5. M, WAM 63.121, dorsal valve interior x 9; N, WAM 74.1301b, ventral valve interior x 5; Q-S, WAM 3523 (SEM) holotype. Q, dorsal valve exterior x 11.4; R, anterior commissure x 20; S, lateral margin x 13.
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from the Late Eocene-Miocene, *L. circularis* Allan, 1932 from the Early Oligocene-Miocene, *L. pitteesis* Allan, 1932 from the Early - Mid Pliocene, *L. skinneri* Allan, 1932 from the Late Miocene-Pliocene, and *L. thomsonii* Allan, 1932 from the Middle-Late Miocene are subcircular while *L. archboldi* is ovate to elongate. *L. boehmi* Thomson, 1918, from the Early Miocene is also subcircular, the width 77% of shell length, and longer, up to 45 mm while *L. archboldi* is up to 33 mm. *L. elongata* Allan, 1932 from the Early-Late Miocene and *L. neglecta* (Hutton, 1905) from the Early Miocene are small (7 mm and 11.5 mm respectively) while *L. archboldi* is medium-sized ranging from 15.7 to 32.8 mm in length. *L. neglecta* (Hutton, 1905) has a more depressed shell, a feature not present in *L. archboldi*. *L. gigantea* (Allan, 1932) from the Middle Oligocene has “wavy radial striae” (Allan, 1937), structures which are not present on *L. archboldi.*

*L. vitriodes* (Tenison-Woods) from the Late Oligocene-Miocene, Table Cape Tasmania (Tate 1899) is small, smooth, subcircular with a small foramen. Previously the oldest record of *Liotynella* were the Late Eocene species *L. concenterica* (Hutton, 1873) and *L. pulchra* Thomson, 1918. Cooper (1981, 1982 and 1983) has described a number of species of Recent *Liotynella* from Antarctica, southern South America, the Falkland Islands, the southern Indian Ocean, Australia and New Zealand.

This is the oldest known record of the genus.

**Etymology**

After Prof. Neil W. Archbold, Professor of Palaeontology, Deakin University, Victoria, Australia, an accomplished Permian brachiopodologist.

**Family Zenobiathyridae fam. nov.**

**Genus Zenobiathyris gen. nov**

**Type Species**

*Zenobiathyris mutabilis* sp. nov.

**Diagnosis**


**Etymology**

From Zenobia, the name of my wife, and the queen of Palmyra in the third century AD, meaning “her father’s jewel”.

**Genus Zenobiathyris mutabilis* sp. nov.**

**Figures 10 A-O**

**Material Examined**

**Holotype**

WAM 83.3148, Range paddock, 2.3 km west northwest of Whitlock Dam, Giralia Station, Giralia Range, Carnarvon Basin, Miria Formation, Maastrichtian.

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Late Cretaceous brachiopods

**Paratypes**
WAM 83.3011, 83.3115, 83.3148, Gully draining east of Bullara-Giralia Road, Giralia Station, Giralia Range, Carnarvon Basin, Miria Formation, Maastrichtian.

**Other Material**
- Gingin Chalk: WAM 74.1176, Meanarra Hill; WAM 88.189, Murchison House Station; Toolonga Calcilutite, Carnarvon Basin, Santonian-Campanian.
- Toolonga Calcilutite: WAM 97.708, Ajana; WAM 84.393/7, Giralia Range, Korojon Calcarenite, Carnarvon Basin, Campanian-Maastrichtian.
- Korojon Calcarenite: WAM 84.393/7, Giralia Range, Korojon Calcarenite, Carnarvon Basin, Campanian-Maastrichtian.
- Miria Formation: WAM 60.109, 60.23, 60.60, 71.152, 71.180, 71.243-245, 71.289, 71.311, 71.477, 74.588, 80.669, 80.695, 80.789, 80.885, 80.948, 80.952, 83.2911, 83.2959, 83.2990, 83.3011, 83.3095, 83.3115, 83.3148, 83.3152, 83.3160, 83.3162, 83.3165-1696, 84.389, 84.391-393, 84.397, 84.429, 84.902, 84.907, 84.921, 84.947, 85.319, 88.126, 88.91-93, 89.1279, 89.1279, 92.702-704, 96.820, 96.821, 96.829, 96.837, 96.834-845, 96.860, 96.861, 96.866, 96.881-882, 96.900, 96.918, 96.923, 96.931-933 Giralia Range, Carnarvon Basin, Miria Formation, Maastrichtian.

**Diagnosis**
- As for genus.

**Description**
- **External.** Medium-sized subpentagonal shell, length from 5.4 to 25.9 mm. Biconvex, both valves to same degree; bulbous, depth 50-75% of shell length, deepest at or near mid-length. Width 80-85% of shell length, widest anterior to mid-length.
- Ribbed with 3-5 ribs per mm at mid-length; growth lines prominent, creating rugose appearance at intersection with ribs. Cardinal margin strongly curved; lateral margin straight, crenulate for anterior two thirds; anterior valve edge bevelled, anterior commissure rectimarginate to uniplicate, often squared or curved inwards giving a “bitten off” (strangulate) appearance; many specimens ornithellid, with two sulci, one on each valve, producing a rectimarginate to slightly uniplicate anterior commissure, many have a marked flattening of the anterior composed of several layers or growth lines. Umbo stout, suberect; beak ridges attrite, beak margins extend to lateral margin. Foramen large (9% of shell length), round, mesothyridid. Symphytium acute and small; deltoidal plates conjunct.
- **Internal.** Ventral valve. Hinge teeth angled into shell, convex, delicate with no plates and bases not swollen. No muscle scars apparent.

**Remarks**
There is a large degree of variation within the species. At one extreme the depth is 50-60% of shell length, greatest depth being posterior to mid-length. Shell ribbing is less numerous with up to 3 ribs per mm. The ribs are not as raised and thus rugose nature is less pronounced. At the other extreme the depth is 70-75% of shell length, the ribs are more numerous (5 ribs per mm) and the pattern is more rugose. The foramen, beak, margins and general outline are the same over the whole continuum.

There is also a continuum with respect to the number of growth lines. At one end are those which are flatter and have less growth lines. The longest specimens fit this pattern. The shorter specimens which are more bulbous tend to be the ornithellid specimens and have the "bitten off" (strangulate) appearance at the anterior commissure. They also have a greater number of growth lines per mm. This suggests a variance in growth rates between the two forms.

**Etymology**
From the Latin “mutabilis” meaning changeable or fickle, referring to its variation in shape.

_Zenobiathyris plicatilis_ sp. nov.

Figure 9 C-H
Figure 10  A–O, *Zonobathiris mutabilis* sp. nov. A–C, E, WAM 83.3011, paratype. A, dorsal valve view; B, ventral valve view; C, lateral view; E, anterior commissure. All x 3; D, F, G, WAM 83.3148b, paratype. D, lateral view; F, anterior commissure; G, dorsal valve view. All x 3. H, K, L, WAM 83.3148a, holotype. H, lateral view; K, anterior commissure; L, dorsal valve view. All x 3. I, WAM 83.3115a, paratype, ventral valve interior x 3; J, WAM 83.3115b, paratype, dorsal valve interior x 3; M, WAM 80.885a, (larger variant) dorsal valve view x 2; N, WAM 87.708, lateral view x 4; O, WAM 80.885b, anterior commissure x 2.
Late Cretaceous brachiopods

Material Examined

*Holotype*

*Paratype*

*Other material*
WAM 74.1263, McIntyres, WAM 76.2245, Hosking’s Chalk, Gingin; WAM 4596a, Molecap Hill, Gingin; WAM 79.2329, WAM 80.402, “Kyno”, Dandaragan; WAM 4240-1, 80.737/744, “Kayanaba”, Dandaragan; WAM 63.128, “Yatheroo” Dandaragan, Gingin Chalk, Perth Basin, Santonian-Campanian.

*Diagnosis*
*Zenobia thyrhis* with distinct uniplicate anterior commissure; 7 ribs per mm; ribs not producing rugose appearance.

*Description*
*Exterior.* Small ovate to pyriform shell to 7.7 mm. Biconvex, depth to 50% shell length. Width greatest anterior to mid-length, to 90% shell length. Growth lines distinct; constellate, 7 ribs per mm, rounded, ribs same width as trenches. Cardinal margin short, curved, to 40% shell length; lateral valve edge bevelled, lateral margin straight posterior two thirds, curves towards dorsal valve anterior third; anterior commissure uniplicate, plication 50% shell width. Umbo stout, curved; beak suberect; beak ridges attrite. Foramen relatively large to 8.5% shell length, submesothyridid; deltoidal plates conjunct. Symphynium narrow, flat, corrugated.


Dorsal valve. Outer socket ridge slight thickening of margin. Sockets large, floor concave, corrugated. Inner socket ridge high, slightly overhangs socket. Crural base fused to inner socket ridge; no hinge plates discernible. Crural process sharp point; loop appears short at end of parallel crura. Cardinal process laterally elongate, thin, striated, fused to inner socket ridge distally; other internal features obscured.

*Remarks*
This species is similar in many respects to *Zenobia thyrhis mutabilis*. The anterior plication is much more pronounced and the number of ribs per mm is nearly double (7:4) that of *Z. mutabilis*. The cardinal margin of *Z. plicatilis* is more curved than that of *Z. mutabilis*. The specimens examined are on average smaller than *Z. mutabilis* for the same number of distinct growth lines. The interaction between the growth lines and costae do not produce a rugose appearance in *Z. plicatilis* unlike those of *Z. mutabilis*. These features are considered to be of specific importance.

*Etymology*
From the well developed fold or anterior plication which is much more pronounced in *Z. plicatilis* unlike that in *Z. mutabilis*.

*Superfamily Cancellothyrioidea Thomson, 1926*

*Family Cancellothyrididae Thomson, 1926*

*Subfamily Cancellothyridinae Thomson, 1926*

*Genus Terebratulina d’Orbigny, 1847*

*Type Species*
*Anomia retusa* Linne, 1758.

*Terebratulina kendricki* sp. nov.

*Material Examined*

*Holotype*
WAM 71.310, Toothawarra Creek, Cardabia Station, Giralia Range, Carnarvon Basin, Miria Formation, Maastrichtian.

*Paratypes*
WAM 96.834, Toothawarra Creek, Cardabia Station, WAM 96.845, north east side of West Tank, Giralia Station, Giralia Range, Carnarvon Basin, Miria Formation, Maastrichtian.

*Other Material*
WAM 71.152, 80.670, 96.922, locality as for holotype.

*Diagnosis*
Small to medium-sized, ovate to pear-shaped shell, biconvex; costae bifurcating anterior to umbo. Anterior commissure uniplicate; beak suberect; foramen large, deltoidal plates disjunct. Loop small ring developed from inward curved crural processes.

*Description*
*Exterior.* Medium-sized shell, 1.7 mm–11.1 mm long, longest specimen 8.0 mm wide, 3.9 mm deep.
Biconvex, dorsal valve flatter; pear shaped to subpentagonal in shape. Widest at the mid-length. Anterior half rounded, posterior half tapering to umbo, deepest at posterior (a quarter distance from posterior umbo) to mid line. Costate rounded, interstitial spaces wider than ribs, 6 ribs / mm, bifurcating just anterior to umbo. Numerous growth lines, most indistinct; form rugose pattern in contact with costae in posterior 2/3 of shell; finely and densely punctate. Cardinal margin 59% shell width, deepest at posterior (a quarter distance from anterior umbo) to mid line. Costate rounded, bevelled, anterior commissure incipiently concave curving towards dorsal valve posteriorly and anteriorly. Slight anterior depression in ventral valve; anterior valve edge bevelled, anterior commissure incipiently uniplicate. Ventral umbo curved, beak suberec, beak ridges rounded. Dorsal umbo protuberant, strongly rounded with “wings” created by inner socket ridges. Foramen large, 10% shell length, round, hypothryrid in juveniles, submesothyrid to mesothyrid in mature specimens; deltoidal plates triangular, disjunct, partially obscured by protuberant cardinal area, palintrope slightly concave.

Interior. Dorsal valve. Outer socket ridges narrow, short. Sockets long, shallowing towards anterior forming a platform. Inner socket ridges high, slightly curved over socket, protuberant over cardinal margin. Crura angled towards centre of valve where a ring loop is formed, slightly offset with dorsal section posterior to ventral section. Cardinal process small, slightly depressed anteriorly with two small lobes posteriorly.

Remarks

*T. buckmani* Owen, 1980 from the “Lower Tertiary” of Cockburn Island, Antarctica, is larger reaching up to 25 mm in length, is oval in shape and possesses an extensive interarea (Owen 1980) in contrast to *T. kendricki* which reaches to 11 mm in length. Biconvex, bulbous, depth 66% shell length. Widest anterior to mid-length, width 82% shell length. Growth lines distinct, few; costellate, 6 ribs per mm at mid-length, bifurcating, spinose in small specimens. Cardinal margin narrow, nearly straight; lateral valve edge rounded, lateral margin straight, crenulate anterior to mid-length; anterior commissure rectimarginate, crenulate. Umbo relatively large, beak sub erect.

from a *Terebratulina* species from the Cardabia Formation, Late Paleocene, Carnarvon Basin which is rectimarginate. *T. kendricki* in having 6 ribs per mm differs from another *Terebratulina* from the Late Middle Eocene Nanarup Limestone, Bremer Basin, Western Australia which has 5 ribs per mm and is unisulcate. This is the earliest record of *Terebratulina* in the Southern Hemisphere.

Etymology

After Mr George Kendrick, Research Associate of the Western Australian Museum who has collected numerous specimens of the species.

**Family Chlidonophoridae Muir-Wood, 1959**

**Genus Gisilina Steinich, 1963**

**Type Species**

*Terebratula gisii* Roemer, 1840.

*Gisilina ovata* (Etheridge, 1913)

Figure 6 K-P

1913 *Terebratulina ovata* Etheridge: 14, pl. II, figs 17, 18.

1993 *Gisilina ovata* McNamara et al.: 4, figs 7, 8.

**Material Examined**

The holotype is missing from the collection. A neotype is not recorded as no taxonomic problem exists.

**Other Material**

Gingin Chalk: WAM 76.2224, Gingin; WAM 5934, Musk’s Chalk, Gingin; WAM 4573, 5403, One Tree Hill, Gingin; WAM 4528, 5622, Hosking’s Chalk, Gingin; WAM 6706, 68.622, 74.1134, Molecap Hill, Gingin; WAM 87.327, McIntyre’s Gully, Gingin; WAM 4283/4, Round Hill, “Kayanaba”, Dandaragan; WAM 79.2330, “Kyno”, Dandaragan; Gingin Chalk, Perth Basin, Santonian-Campanian.

Toolonga Calcilutite: WAM 79.2915, Meanarra Hill; WAM 88.204, Murchison House Station; Toolonga Calcilutite, Carnarvon Basin, Santonian-Campanian.

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Toolonga Calcilutite: WAM 79.2915, Meanarra Hill; WAM 88.204, Murchison House Station; Toolonga Calcilutite, Carnarvon Basin, Santonian-Campanian.

**Description**

*Exterior.* Small pyriform to subpentagonal; shell up to 5 mm in length. Biconvex, bulbous, depth 66% shell length. Widest anterior to mid-length, width 82% shell length. Growth lines distinct, few; costellate, 6 ribs per mm at mid-length, bifurcating, spinose in small specimens. Cardinal margin narrow, nearly straight; lateral valve edge rounded, lateral margin straight, crenulate anterior to mid-length; anterior commissure rectimarginate, crenulate. Umbo relatively large, beak sub erect;
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beak ridges indistinct from ribs. Foramen rounded, incomplete, 8% shell length, mesothyridid; deltidal plates disjunct, interarea wide to margin, concaved.

**Interior.** Ventral valve. Valve deep. Teeth with swollen bases, short deltiodont; groove between teeth and margin. Muscle scars indistinct.

Dorsal valve. Outer socket ridge narrow. Sockets short, nearly coincident with cardinal margin in some specimens. Inner socket ridge curved over sockets to 50%, fused to crural base; no clear hinge plates. Crura extend inwards from extremities of fused bases. No complete loop. No median septum. Low median ridge separates small round muscle scars; ridge extends to cardinal process. Cardinal process rounded concave knob, swollen anteriorly.

**Remarks**

This species was first described by Etheridge as a *Terebratulina* (Etheridge 1913). Ms F. S. Dodds, a voluntary worker at the Western Australian Museum, tentatively reclassified it as *Gisilina*. McNamara et al. (1993) included it in his description of fossils from the Gingin Chalk. This species fits the generic description of *Gisilina*. This species is distinct from *Gisilina gisii* (Roemer, 1840) in that it is ovate and the umbo is relatively large. Previously it has been recorded from the Late Cretaceous of Europe. No other species of this genus has been recorded from the Southern Hemisphere.

**Family Inopinarcturalidae Muir-Wood, 1965**

**Genus Inopinarctura Elliott, 1952**

**Type Species**

*Trigonoseniiis acanthodes* Etheridge, 1913.

**Inopinarctura acanthodes** (Etheridge, 1913)

Figure 5 M-O, 6 A-B

1913 *Trigonoseniiis acanthodes* Etheridge: 15, pl. 2, figs. 1–4.

1952 Inopinarctura acanthodes Elliott: 2, pl. 2, figs. 22–27.


1983 *Inopinarctura acanthodes* Cooper: 224–225, pl. 26, figs. 19–26, pl. 75, figs. 21,22.


**Material Examined**

The original described specimen WAM 3521 is missing and hence it is impossible to erect lectotype or parallectotypes. A neotype is not selected as there is no taxonomic problem.

**Other Material**

Gingin Chalk: WAM 4574; 5117-5126; 68.656-658; 74.1289-89, 75.1200, One Tree Hill, Gingin; WAM 74.1302; 75.5; 76.2245; 82.2660, Spring Gully, Gingin; WAM 6154-55; 77.2758; 82.329; McIntyre’s Gully, Gingin; WAM 67.393; 68.110, 578, 588, 619, 621; 74.530, 1133,1135, 1139, 1170; 75.1186, 1189;76.2221; 77.2754; 87.341; 88.903; 91.806, Molecap Hill, Gingin; WAM 4525, Hosking’s Chalk, Poison Hill, Gingin; WAM 5414; 5936, Musk’s Chalk, Gingin; WAM 4553-5; Spuff’s Chalk, Gingin; WAM 3831; 3851; 63.105-6; 70.1835; 78.280; 87.244; 88.893, Gingin; WAM 63.126, 130; 77.3546; 80.738-39742, “Yatheroo”, Dandaragan; WAM 4242, 4249-59, 4261, 4276; 63.120; 77.3528, 3535; 78.949-50, 4217, 4191-5, 4335, 4349, 4357, 4360, 4368, 4407, 80.399, 401, 744, 1310, 1312, 92.661, “Kayanaba”, Dandaragan; WAM 79.2329, 2333, 2338, 80.402, “Kyno”, Dandaragan; WAM 70.1809, Glenlark Farm, Dandaragan; WAM 79.2346, “Minyulo”, Dandaragan; WAM 78.4389, 4395, 4408, 4418, 4441, 4453, 4542; 79. 2267, 2271, 2293, 2303; 80.697, “Noondal-Wandilla”, Dandaragan; Gingin Chalk, Perth Basin, Santonian-Campanian.

Toolonga Calcilutite: WAM 74.1176, 1178, 75.11, 79.2913, 80.1017, 84.1749, 88.314, 94.6, Meanarra Hill; WAM 84.1748; 88.197-8, 232, 245, 251-2, 276, 280, 872; 92.737; 94. 303, 316, 533, 546, Murchison House Station; WAM 87.618, Yaringa Station, Shark Bay; Toolonga Calcilutite, Carnarvon Basin, Santonian-Campanian.

**Description**

**External.** Circular to sub-circular shell to 30 mm long. Biconvex valves, both to same degree; depth 65% of shell length. Widest at mid length or anterior to it, width 95–100% of shell length. Deep sulcus in ventral valve extending just posterior to cardinal margin, dorsal valve with strong fold, anterior width 43% of shell length. Capillate, up to 7 ribs per mm at mid-length, ribs shallow, bifurcate; very finely densely punctate; growth lines distinct, numerous. Cardinal margin gently curved, lateral valve edges bevelled, lateral margin strongly curved, convex with respect to dorsal valve; anterior commissure strongly uniplicate, plication 33% of shell length, edge bevelled. Umbo short, beak erect, beak ridges rounded. Foramen small, 1–2% of shell length, round, permesothyridid; deltidal plates conjunct; symphytium small, triangular, concave, horizontally striated.

**Internal.** Ventral valve. Socket teeth cyrtomatedont, long, 9.5% of shell length, width 6.3% of shell length, thickest (4.3% of shell length) anteriorly, buttressed against thickened lateral margin, series of curved lamella extending from lateral margin anteriorly (corrugated), slight concave depression next to lateral margin.
Diductor muscle scars shaped like tear drops either side of slightly raised platform below umbo, 26% shell length. Lateral diductor scars long and thin; small scars posterior to diductor scars short and raised; median fold begins anterior to muscle scars.

Dorsal valve. Outer socket ridges thin. Socket in thickened buttressed area of lateral margin, socket triangular, 12% of shell length. Inner socket ridge wide, curves partially over socket. Inner hinge plate concaved, joins crural base area strongly laminated. Crural process short, rounded; crura triangular, apex posteriorly, widening greatly to loop. Loop short, width 30% shell length, arched towards ventral valve; muscle scars round with thickened valve floor creating a heart shape posteriolaterally. Median septum low, flattened, short (33% shell length), widening posteriorly forming low trough, extends to base of cardinal process. Cardinal process thin vertically striated concave band 4.5% shell length.

Remarks
The above description accords well with those provided by Elliott (1952) and Cooper (1983). The specimens from Dandaragan are larger than those from Gingin and have a correspondingly deeper anterior sulcus.

**Suborder Terebratulidina Waagen, 1883**
**Superfamily Terebratelloidea King, 1850**
**Family Dallinidae Beecher, 1893**
**Subfamily Gemmarculinae Elliott, 1947**
**Genus Gemmarcula Elliott, 1947**

*Type Species*
*Terebratula truncata* Sowerby, 1826.

*Gemmarcula doddsae* sp. nov.
Figure 9 I-K

**Material Examined**

*Holotype*

**Diagnosis**
Cardinal process fused to cardinal margin, foramen trapezoid, hypothyridid, anterior commissure unisulcate.

**Description**
*Exterior.* Small to medium subcircular shell to 14.4 mm in length. Biconvex, depth 52% shell length. Width greatest at mid-length, 90% shell length. Finely and densely punctate, costellate, growth lines numerous distinct, sulcus extends from cardinal to anterior margins. Cardinal margin wide, nearly straight; lateral valve edge bevelled, lateral margin gently curved to dorsal valve; anterior commissure unisulcate, finely crenulate. Umbo short, wide, erect; beak ridges sharp. Foramen trapezoid, large, 14% shell length, hypothyridid; interarea concave, striated.

*Interior.* Ventral valve. Teeth unclear, no dental plates. Muscle scars wide, short, pyriform, indented anteriorly, separated by ridge widening into a platform.

Dorsal valve. Socket and outer socket ridges obscured. Inner socket ridge, crural bases and outer hinge plates fused. Inner hinge plate extends across median area in narrow shallow septalium fused to cardinal process and cardinal margin. Median septum short, 31% shell length, rises to the loop projecting above lower transverse band, descends to form broadening ridge consistent with sulcus. Crural process short, triangular with rounded apex; descending branches join median septum widely rising to narrow slightly; loop incomplete. Cardinal process hemispherical, horizontally striated, fused to cardinal margin. Muscle scars indistinct, elongate, lie within shallow ridges either side of median septum.

**Remarks**
This species differs from others referred to *Gemmarcula* in that it has a trapezoid hypothyridid foramen and the anterior commissure is distinctly unisulcate.

**Etymology**
After Mrs Frances S. Dodds who spent much time as a voluntary worker at the Western Australian Museum, collecting and sorting specimens, especially those from the Gingin Chalk.

**Family Kingenidae Elliott, 1948**
**Subfamily Kingeninae Elliott, 1948**
**Genus Kingena Davidson, 1852**

*Type Species*
*Terebratula lima* Defrance, 1828.

*Kingena mesembrina* (Etheridge, 1913)
Figure 7 A–K

1913 *Magas mesembrinus* Etheridge: 15, pl. 2, figs 5–8, 8a

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1965 *Kingena mesembrina* Muir-Wood: H839, figs 725, 1a-h.

1970 *Kingena mesembrina* Owen: 69, pl. 6, figs 9a-c.

1991 *Kingena mesembrina* Sandy: 403.

1993 *Kingena mesembrina* McNamara et al.: 4, figs 11, 12.

**Material Examined**

**Holotype**

WAM 3522, McIntyre’s Gully, Gingin, Gingin Chalk, Perth Basin, Santonian-Campanian.

**Other material**

Gingin Chalk: WAM 5209,10; 5288; 5291; 6429; 68.618, 624; 74.1141; 75.1190; 84.310; Molecap Hill, Gingin; WAM 89; 74.1138, 1265, 1273; McIntyre’s Gully, Gingin; WAM 5127, One Tree Hill, Gingin; WAM 5985-90; 63.107; 70.1832; 76.2223; 82.1938, 2660, Gingin; WAM 4526; 5623, Hosking’s Chalk, Gingin; WAM 5675, Southern’s Chalk, Gingin; WAM 5940,43,45, Musk’s Chalk, Gingin; WAM 4552, Spuff’s Chalk, Gingin; WAM 74.1301; 82.2665, Spring Gully, Gingin; WAM 63.127, “Yatheroo”, Dandaragan; WAM 477; 4281; 4234; 4245-6; 78.4358; 79.1032; 80.400, 1311, “Kayanaba”, Dandaragan; WAM 80.698, “Kyno”, Dandaragan; WAM 79.2347/49, “Minyulo”, Dandaragan; WAM 78.4440; 79.1033-4, 2270; 80.1303, “Noondal-Wandilla”, Dandaragan; Gingin Chalk, Perth Basin, Santonian-Campanian.

Toolonga Calcilutite: WAM 74.1177, 1179, 1180; 75.9; 78.932; 79.2914; 88.315, 316, 885; 94.5, Meanarra Hill; WAM 94.315, 534, Murchison House Station; Toolonga Calcilutite, Carnarvon Basin, Santonian-Campanian.

**Description**

**External.** Medium sized ovate to subpentagonal shell up to 22 mm in length. Biconvex, the dorsal valve variable (depth 45%-69% shell length) to almost flat. Widest at mid-length, width 87% shell length. Punctae dense, elongate; growth lines numeros and distinct. Cardinal margin gently curved to almost straight, lateral valve edge bevelled, lateral margin straight to sigmoidal; anterior commissure variable from incipiently unisulcate to rectimarginate to uniplicate; umbo narrow, overlapping dorsal valve in some specimens. Umbo truncated, beak suberect to erect. Foramen round medium sized, 8.3% of shell length; mesothyridid to permesothyridid. Deltidal plates conjunct in larger specimens, disjunct in smaller specimens, symphytium small almost hidden by overlapping umbo, thin, concave.

**Internal.** Ventral valve. Hinge teeth developed from deltidal plates or appear so, teeth flat, curved towards posterior, curved groove on anterior side, protuberant towards dorsal valve at angle less than 45°; cyrtomatodont. Dental plates present forming triangular cavity under teeth, strongly ribbed horizontally. Pedicle collar striated horizontally reaches to base of dental plates. Muscle scars tear drop-shaped just beside dental plates. May or may not have median ridge; ridges may be present at anterior of muscle scars which bifurcate anteriorly.

Dorsal valve. Outer socket ridges wide, extend anteriorly. Socket shallow depression extending inwards to form shallow reception area. Inner ridges narrow, fused to outer hinge plates; crural base extends from fused inner socket ridges and outer hinge plates horizontally and anteriorly. Inner hinge plates form septalium with short thin median septum. Loop consists of narrow descending bands extending anteriorly, spines present anterio-laterally, secondary bands extend from initial bands posteriorly, incurved, meet at anterior of median septum. Vertical extension of median septum bifurcates thickly forming two bands which reunite, form circular hole posteriorly, raised curved plate or anteriorly facing hood. Brachidium and incipient muscle scars housed in shallow depressed hollow within valve. Anteriorly a wide low ridge separates depression from rest of valve. Valve turns outwards anterior to dividing ridge. Cardinal process wide laterally, narrow longitudinally, consists a central small shallow depression with two larger depressions either side, connected laterally to valve margin or slightly raised and narrowly bulbous.

**Remarks**

The above description is consistent with that provided by Etheridge (1913) and Elliott (1952). Elliott’s specimens are unnumbered and therefore difficult to trace in the University of Western Australia’s geological collection. It is difficult to identify true transverse connecting bands in some specimens as these are incurved posterior extensions of the descending bands. The hood is variably developed in juvenile (small) and adult (large) specimens, being short to long in extension anteriorly.

**Family Terebratellidae King, 1850**

**Subfamily Bouchardiinae Allan, 1940**

**Genus Bouchardiella Doello-Jurado, 1922**

**Type Species**

*Bouchardiella patagonia* Ihering, 1903.

*Bouchardiella cretacea* (Etheridge, 1913)

Figure 7 L-S

1913 *Magassela cretacea* Etheridge: 16, pl. 2, figs 9-12.
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Material

Lectotype

WAM 3523, Molecap Hill, Gingin, Gingin Chalk, Perth Basin, Santonian-Campanian.

Parallectotypes

WAM 99.434, as for lectotype.

Other material

Gingin Chalk: WAM 3829, 3937, 3968, 63.104; 76.2222, 2233, 78.279, Gingin; WAM 4524, 5624, 76.2244, Hosking’s Chalk, Gingin; WAM 74.1299, 75.4, 76.2233, Spring Gully, Gingin; WAM 4551, Spiff’s Chalk, Gingin; WAM 5673-4, Southern’s Chalk, Gingin; WAM 5415, 5914, 5933, Musk’s Chalk, Gingin; WAM 5362, 5381, Compton’s Chalk, Gingin; WAM 76.2254, Dodd’s Chalk, Gingin; WAM 5179, 5208, 5227, 5286, 6433, 6442; 68.594, 618, 620, 623; 71.1137, 1140; 75.1187, 87.343; 91.278, 894, 92.668, Molecap Hill, Gingin; WAM 74.1266, 87.330, McIntyre’s Gully, Gingin; WAM 5341, 5350, 68.599, 659, 71.493, 74.1287, 75.1201, 82.2666, 86.1416, One Tree Hill, Gingin; WAM 63.121; 77.3530, 3534; 78.4198, 4367, 79.1029-31, 92.660, 664, “Kayanaba”, Dandaragan; WAM 78.4419; 79.2288, 2295, “Noondal-Wandilla”, Dandaragan; WAM 79.2232, “Kyno”, Dandaragan; WAM 63.134, 139; 77.3541,3547, “Yatheroo”, Dandaragan; Gingin Chalk, Perth Basin, Santonian-Campanian.

Toolonga Calcilutite: WAM 74.1174, 79.2916, 88.813, 883, Meanarra Hill; WAM 88.196,219,250; 94.314, Murchison House Station; Toolonga Calcilutite, Carnarvon Basin, Santonian-Campanian.

Miriia Formation: WAM 80.671, 88.52, CY Creek, Cardabia Station, Giralia Range, Carnarvon Basin, Miria Formation, Maastrichtian.

Description

Exterior. Small subcircular shell, subtriangular in larger specimens 2-10 mm long. Biconvex, dorsal valve almost flat. Widest slightly anterior to mid-length, width 90% shell length in small specimens, 82% in large. Finely and densely punctate, punctae oval; growth lines numerous anterior to mid-length, prominent. Cardinal margin short, nearly straight, lateral and anterior valve edges bevelled, lateral margin sigmoidal, anterior commissure deeply unsulcate, sulcus greater than 50% shell width. Umbo truncated; beak straight to slightly suberect; beak ridges sharp. Foramen small, 3% shell length, permesothyridid; deltital plates conjunct. Symphytium triangular, striated, striations form obtuse angle and middle of symphytium.


Dorsal valve. Cardinal area contained in platform extending between lateral margins. Outer socket ridge indistinct from margin. Socket wide gently concave, extends laterally into valve space. Inner socket ridge overhangs socket slightly. Crural base, outer hinge plates fused; crura extends anteriorly from fused plates. Inner hinge plates striated, fused to median septum constructing short septalium. Median septum thin, extends beyond mid-length, anteriorly bifurcates to produce anterior section of loop. Loop incomplete. Pyriform muscle scars either side median septum. Narrow low ribs extend beyond median septum to anterior margin from muscle scar anterior. Cardinal process slight thickening of cardinal margin, raised slightly laterally.

Remarks

The description is consistent with that provided by Etheridge (1913) and Elliott (1952). Elliott’s description was based on 62 unnumbered specimens in the collection of the Geological Department of the University of Western Australia. A larger specimen (10 mm) was available giving some differences in general shape, a product of ontogeny.

Indeterminate terebratulid genus 1

Figure 11 A-C

Material

WAM 88.873, Murchison House Station, Toolonga Calcilutite, Carnarvon Basin, Santonian-Campanian.

Description

Exterior: Small to medium, ovate to subpentagonal shell up to 14 mm in length. Biconvex, depth 80% shell length. Width 71% shell length, widest at mid-length. Finely and densely punctate, growth lines distinct; multiplicate anterior, 25% of shell width, 7 ribs per mm at anterior commissure. Cardinal margin wide to lateral margin, strongly curved; lateral valve edge steeply rounded, lateral margin straight to anterior boundary, rises sharply; anterior valve edge rounded to squared, anterior commissure unsulcate, sulcus taking up whole margin,
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Indeterminate terebratulid genus 2

Figure 11 D-E

Material

WAM 74.1262, McIntyre’s Gully, Gingin, Gingin Chalk, Perth Basin, Santonian-Campanian.

Description


Remarks

Only one specimen of this species has been recovered to date. No internal structure is available. The disjunct nature deltidal plates may be a product of weathering.
greatest at mid-length, 9.7 mm. Finely and densely punctate, growth lines distinct. Cardinal margin gently curved, wide, inner socket ridges overhang margin; lateral margin straight; anterior commissure rectimarginate.


**Indeterminate terebratulid genus 3**  
Figure 11 F-H  

**Material**  
WAM 76.2329, Molecap Hill, Gingin; WAM 79.2331, "Kyno", Dandaragan, Gingin Chalk, Perth Basin, Santonian-Campanian.

**Description**  
**Exterior.** Sub-circular medium-sized shell to 19.8 mm in length. Biconvex, depth 66% shell length. Width greatest anterior to mid-length, 93% shell length (or greater). Finely punctate, growth lines distinct, multiplicate, 6 folds on each valve. Cardinal margin gently curved, wide; lateral valve edge gently bevelled, lateral margin straight, crenulate anteriorly; anterior commissure incipiently unisulcate, crenulate. Umbo stout, curved; beak erect; beak ridges attrite. Foramen large, incomplete in specimen, mesothyridid; deltidial plates probably conjunct. Symphytium concave.

**Interior.** No interiors available.

**CONCLUSIONS**

The brachiopod faunas of the Late Cretaceous of Antarctica and the Late Cretaceous of Western Australia show a number of similarities (Table 1) supporting the suggestion that the western coast of Australia was part of a continuous shelf extending all the way to the Antarctic Peninsula. The shelf with the associated brachiopod fauna formed the southern circum Indo-Atlantic province during the Late Cretaceous to Palaeogene. *Tegularhynchia* is recorded from the Santonian-Campanian deposits of Western Australia. *Tegularhynchia* is recorded from the Santonian-Campanian deposits of Western Australia. It is recorded in the "Lower Tertiary" of Cockburn Island, Antarctic Peninsula (Owen 1980) and the Late Paleocene of the Cardabia Formation, Carnarvon Basin Western Australia (McNamara 1983). This genus had a long history in the southern circum Indo-Atlantic province.

The presence of *Liothyrella lecta* (Guppy, 1866) and *L. anderssoni* Owen, 1980 from "Early Tertiary" deposits of Cockburn Island and Seymour Island, Antarctic Peninsula respectively (Owen 1980) and *L. archboldi* and *L. brimmellae* from the Late Cretaceous of Western Australia (the first known occurrence of the genus) indicates that this genus may have first evolved in the higher latitudes during the Cretaceous. That *Liothyrella* is known from the Paleogene and Recent of Antarctica, the subantarctic waters, south-eastern Australia and New Zealand may best be explained by the genus persisting on the Antarctic shelf during the Paleogene and migrating west to east whilst the gap between Australia and Antarctica opened in the Late Eocene.

**Terebratulina** is a cosmopolitan genus, and its presence in the Miria Formation during the Late Cretaceous is not unexpected. It may have migrated into the region, possibly through the Tethyan realm. *Bouchardiella cretacea* occurred on the western coast of Australia. This genus is also known from the Cretaceous of South America (Doello-Jurado 1922). A related genus, *Bouchardia* (*B. antarctica* Buckman, 1910) is recorded from the "early Tertiary" of Seymour Island, Antarctic Peninsula (Buckman 1910, Owen 1980, Bitner 1996). Owen (1980) described a "Terebratula" species which is externally similar to *Zenobiathyris*. If a species of *Zenobiathyris*, it shows a wide distribution of the family from the Antarctic Peninsula to Western Australia. *Zenobiathyris* is not known from any Palaeogene deposits.

Sampson et al. (1998) have recently proposed a palaeogeographical construction that enables marine faunal migration between India, Madagascar and South America via Antarctica during the Cretaceous. Sandy (1991) suggests a distinct austral brachiopod fauna existed from the Aptian onwards, at least between the Antarctic Peninsula and Western Australia. The presence of *Cretihynchia* and *Retichyris* common to both the Gustav Group and Marambio Group, Aptian to Coniacian, James Ross Island, Antarctica (Sandy 1991) and the Kallankurichi Formation, Early Maastrichtian, India (Radulovic and Ramamoorthy 1992) support the hypothesis of Sampson et al. (1998). *Kingena* is common to the Gustav Group and Marambio Group, Aptian to Coniacian, James Ross Island, Antarctica (Sandy 1991) and the Santonian-
Late Cretaceous brachiopods

Table 1  Distribution of species described in Western Australia and Antarctica.

<table>
<thead>
<tr>
<th>Species</th>
<th>Gingin Chalk</th>
<th>Toolonga Calcidilute</th>
<th>Korojon Calcarenite</th>
<th>Miria Form.</th>
<th>Antarctic Peninsula</th>
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<tr>
<td>Bouchardiella cretacea (Etheridge, 1913)</td>
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<td>Gisilina ovata (Etheridge, 1913)</td>
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<td>Laeopinatarcula acuminata (Etheridge, 1913)</td>
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<td>Kingena mesembrina (Etheridge, 1913)</td>
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<td>Protegulorhynchia meridionalis Owen, 1980</td>
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<td>Tegulorhynchia hrodciberti sp. nov.</td>
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<td>Terebratula kaundricki sp. nov.</td>
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<td>Zeobathyris mutabilis sp. nov.</td>
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<td>Zeobathyris plicatilis sp. nov.</td>
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to Campanian Gingin Chalk, Western Australia (Etheridge 1913). The presence of Cretirhynchia and Rectithyris in both India and Antarctica may be explained by the existence of a shallow water corridor between these land masses as proposed by Sampson et. al (1998). The corridor may have lasted for a period between the Aptian and Santonian following which the gap between India and Antarctica became firmly established. This then allowed the migration of Kingena, and possibly other genera, between the Antarctic Peninsula and southwestern Australia.

Liothyrella may have evolved from Rectithyris. Both Liothyrella and Rectithyris are described as being ovate and biconvex with a short broadly triangular loop that is 0.3 times the shell length. Both also have a low laterally extended cardinal process. The difference exists in the foramen which is epithyridid in Liothyrella and mesothyridid in Rectithyris. Cooper (1983) described the foramen of Liothyrella as submesothyridid whilst Thomson (1927) describes it as epithyridid. In Liothyrella archboldi the foramen is permesothyridid, half way between the extremes of those described for Liothyrella and Rectithyris. If Liothyrella did indeed evolve from Rectithyris it would be expected to be found in the southern Indo-Atlantic province. This would account for its presence in the younger Maastrichian deposit of the Miria Formation.

Buckman (1910) described species of Magellania from the Tertiary of the Antarctic Peninsula. This genus also occurs in Australia. Terebratulina lenticularis, Hemithyris squamosa, and Terebratulina bulbosa described by Buckman (1910) from the Seymour Island and Cockburn Island deposits also occur in the Australian “Tertiary” (Tate 1880).

In the Paleogene to Neogene deposits in the Cardabia Formation, Giralia Range, Carnarvon Basin, Western Australia, a number of brachiopods occur (Craig in press) which are also common to the brachiopod fauna of the La Meseta Formation, Antarctic Peninsula of Late Eocene age. These include the genera Basiliola, Tegulorhynchia, Liothyrella and Terebratulina. The genus Cannelclythrysis, which is found in the Cardabia Formation, is still living in Antarctica (Foster 1989).

In summary, brachiopod faunal evidence from both the Late Cretaceous and Paleogene of Western Australia and Antarctica, supports the hypothesis of a southern Indo-Atlantic faunal province with a common shelf existing from the Antarctic peninsula to the western coast of Australia.

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank Dr K. J. McNamara for all his support and encouragement. The Western Australian Museum has been very supportive of the research, providing specimens and equipment. Scanning Electron Microscope photographs were prepared with the assistance of Ms Elaine Miller of Curtin University and Dr Bruce Robinson, CSIRO, Perth.

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*Manuscript received 15 March 1999; accepted 21 June 1999.*
Two new freshwater mites of the genus *Limnohalacaris* (Halacaridae: Acari) from Australia

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Abstract – From Australia, two new species of the genus *Limnohalacaris* are described. *Limnohalacaris australis* sp. nov. from a sinkhole in the east Kimberley, Western Australia, and *Limnohalacaris billabongis* sp. nov. from Corndorl Billabong, Kakadu National Park, Northern Territory. A key is given to the females of this cosmopolitan genus.

INTRODUCTION

The superfamily Halacaroidea, with the single family Halacaridae, comprises almost 900 marine and 50 freshwater species, the latter inhabiting both epigean and hypogean waters (Bartsch, 1996). From Australia, the first record of a freshwater halacarid mite is that of the enigmatic *Astacopsiphagus parasiticus* Viets, 1931, a parasite found fixed to the gills of a parasitic crayfish (Viets, 1931). More than five decades passed by till a second species was added to the fauna of Australia, a species of the widely spread genus *Lobohalacaris*, *L. bunurong* Harvey, 1988, extracted from the sediment of a river bed (Harvey, 1988). Two years later, Harvey (1990) reported on the first Australian representative of *Limnohalacaris*. It is a cosmopolitan genus, known from all continents except Antarctica which has as yet not been studied intensely in respect to its limnic halacarid fauna. In this paper, two species are described, one from the east Kimberley, Western Australia, the other from the Kakadu National Park, Northern Territory.

MATERIAL AND METHODS

One of the halacarid species was taken by S. M. Eberhard in the course of investigations of caves in the Napier Range, part of the Devonian Reef in the Kimberley, Western Australia. It is a large and highly karstic limestone reef, extending for more than 200 km. The collecting site, in the Donnas Drain, is a water-filled low passage with muddy floor, sediment banks at the waters edge, and many tree roots suspended in the water. The collection was made by sweeping a handnet through the water and amongst the tree roots. The other species is from Corndorl Billabong, near Jaribu. In the wet season it is a part of the Magela Creek system which flows into the East Alligator River, Kakadu National Park, Northern Territory.

SYSTEMATICS

Subfamily Limnohalacarinae Viets, 1927

Genus *Limnohalacaris* Walter, 1917

Type Species

*L. wackeri* (Walter, 1914), by original designation.

Diagnosis

AD, OC and PD generally reticulated. Idiosoma with five pairs of gland pores, two or three pairs of dorsal setae and pair of adanal setae. AE with three pairs of ventral setae; PE with three setae. Female GA with three to ten pairs of perigenital setae, male GA with larger number of setae. External acetabula arranged along margins of GA. Gnathosoma with large base. Second pair of long maxillary setae on...
rostrum. Palps four-segmented; P-2 enlarged; P-3 with large spine; fourth segment with six setae and a large spine. Tibia III with two bipectinate ventromedial setae. Tarsi I to IV with 1, 0, 0, 0 ventral setae and, with dorsolateral solenidia included, 4, 4, 4, 3 dorsal setae. Tarsi ending with two claws; claws on tarsi II to IV with numerous long tines.

**Limnohalacarus australis** sp. nov.
Figures 1–2

**Material Examined**

*Holotype*

♀, Donnas Drain (Karst index number KN-42), Kimberley, Western Australia, Australia, 17°15'11"S, 124°41'46"E, 20 July 1998, S. M. Eberhard (WAM 99/2164 BES6166).

**Description**

**Female**

_Idiosoma_ 288 μm long, 205 μm wide. Dorsal plates reticulated, each polygon subdivided. AD rectangular, 75 μm long, 64 μm wide (Figure 1A); pair of gland pores small, placed anterolaterally. Second pair of gland pores ventromarginally, within striated integument between AE and PE (Figure 1B). OC divided transversely; anterior plate rounded, 35–38 μm in diameter; lateral margin with pore canaliculus. Postocular plate slender, triangular, 30 μm long, 11 μm wide; with gland pore anterolaterally. Fourth and fifth pairs of gland pores within striated integument, fourth pair adjacent to insertion of leg IV, fifth pair near posterior margin of PD. PD 176 μm long, 92 μm wide, 1.9 times longer than wide. Dorsal setae small, first pair of setae inserted close together in a raised portion of AD; second pair within striated

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Figure 1  *Limnohalacarus australis* sp. nov., female: A, idiosoma, dorsal aspect; B, idiosoma, ventral aspect; C, gnathosoma, ventral aspect; D, gnathosoma, lateral aspect; E, tip of rostrum and chelicera; F, third and fourth palpal segment, lateral aspect; G, tarsus I, lateral aspect (medial setae and claw omitted); H, tarsus II, lateral aspect (medial setae and claw omitted). (ac, acetabula; as, adanal seta; glp, gland pore; p, basiventral process; pc, pore canaliculus; ph, pharyngeal plate; so, solenidion) Scale lines = 50 μm.
Two new freshwater halacarid mites from Australia

Ventral plates delicately porose; marginal areas of PE foveate. AE 110 µm long, 168 µm wide, posterior margin truncate. Pair of platelets posterior to AE (Figure 1B). PE 137 µm long; with one dorsal, one lateral and one ventral seta. GA 147 µm long, 122 µm wide; with eight and nine acetabula along lateral and posterior margin. One of the three pairs of perigenital setae close to anterior margin of GA, the other two pairs of setae slightly anterior to genital opening. Pair of genital sclerites wide, each sclerite with two subgenital setae.

Gnathosoma 100 µm long, 63 µm wide, length/width ratio 1.6. Base of gnathosoma globular; rostrum very slender. Pharyngeal plate 34 µm long, 18 µm wide, far from reaching posterior margin of gnathosomal base (Figure 1C). Tip of rostrum narrowed (Figure 1E). Palps extending beyond rostrum (Figure 1D). P-1 short, 5 µm long; P-2 enlarged, along its dorsal margin 45 µm long; P-3 17 µm long and P-4 9 µm long. P-2 with one very short and one long seta. Ventromedial spine of P-3 19 µm long (Figure 1F).

Legs I and II shorter than legs III and IV (Figure 2). Genua I and II shorter than telofemora and tibiae (Figure 2A and B); telofemora I and II about as long as these legs' tibiae. Genua and telofemora of legs III and IV almost equal in length (Figure 2C and D); tibiae III and IV much longer than telofemora III and IV respectively. Integument of lateral flanks of leg segments with epicuticular droplets. Tarsi I to IV each with a basiventral process, dentiform at lateral aspect (Figure 1G). Membranes of claw fossae narrow. Setation of legs, from trochanter to tarsus (parambucral setae and solenidia included): leg I, 1, 4, 4, 6, 7, 7; leg II, 1, 3, 4, 6, 6, 6; leg III, 1, 2, 3, 4, 7, 6; leg IV, 1, 1, 3, 3, 6, 5. Tibiae I and II each with bipectinate ventromedial seta; tibia III with two strongly bipectinate ventromedial setae; on tibia IV all setae smooth. Solenidion on both tarsus I and II (Figure 1G and H) on dorsolateral membrane of claw fossa, adjacent to dorsal fossary seta. Famulus not seen. All tarsi with pair of single parambucral setae.

Figure 2  *Limnocalcarus australis* sp. nov., female: A, leg I, medial aspect; B, leg II, medial aspect; C, leg III, medial aspect; D, leg IV, medial aspect (basis of trochanter broken, supplemented by broken line). Scale line = 50 µm.
Tarsi end with pair of claws; each of the claws with basal process. Claws of tarsus I apically with two to three slender tines (Figure 1G); basal process with two tines. Claws on the other tarsi with accessory process and 10-12 tines; basal process with three tines.

Remarks
The most marked characters of adult *Limnohalacarus australis* are: ventral plates AE, PE and GP separate, and claws on tarsus I with few small tines and a basal process. The three species *L. africanus* Walter, 1935, *L. capernaumi* Petrova, 1966 and *L. wackeri* (Walter, 1914) have separate ventral plates but differ from *L. australis* by their claws of tarsus I which bear numerous long tines. Two species, *L. cultellatus* Viets, 1940 and *L. inopinatus* Fain and Lambrechts, 1987, are most similar to *L. australis*. *L. australis* has, in contrast to *L. cultellatus*, a larger number of genital acetabula, and the PD of *L. australis*, with a length/width ratio of 1.9, is more slender than that of *L. inopinatus.*

*Limnohalacarus australis* is a western Australian species. *L. cultellatus* was extracted from wells, ditches and deep crevices on islands of the Lesser Antilles, Caribbean area (Viets, 1940). The homeland of *L. inopinatus* is not known; individuals of the species were found in Belgium, in fish aquaria with cichlids (Fain and Lambrechts, 1987).

*Limnohalacarus billabongis* sp. nov.
Figures 3-5

Material Examined
Holotype
♀, Conondj Billabong, 12°38'S, 132°53'E, Magela Creek system, Kakadu National Park, Northern Territory, Australia, sample no. PA1, 1 March 1983, M. Malipatil, J. Fysan and A. Sharley (NTM).

Paratypes
Australia: Northern Territory: 2 ♀, same data as holotype (NTM); 1 ♀, same data as holotype (WAM 99/2165); 1 ♀, same data as holotype (ZMH).

Other Material
Australia: Northern Territory: 3 ♀, same data as...
Two new freshwater halacarid mites from Australia

holotype except sample no. PA2 (NTM, slides); 1 ?, same data as holotype except sample no. PA3 (NTM, slides); 1 ?, same data as holotype except sample no. PA4 (NTM, slides); 1 ?, sample no. PA4 (SMF, slides); 1 deutonymph, same data as holotype except sample no. PA5 (NTM, slides); 1 ?, 1 deutonymph, same data as holotype except sample no. PB4 (NTM, slides); 12 ?, Kakadu National Park, Magela Creek system, Corndorl Billabong, 4 and 5 February 1983 (NTM); 8 ?, 1 deutonymph, Corndorl Billabong, 1 June 1983 (NTM); 4 ?, same data (author's collection).

Description

Female

Idiosoma 297–342 μm long, holotype 320 μm long, 217 μm wide. Dorsal plates delicately porose and reticulated. Spots of black eye pigment present near anterior margin of AD and beneath anterior portion of OC. AD 83 μm long, 91 μm wide. Anterior margin with very small median process and a pair of small lateral protuberances, each with a gland pore. Posterior margin truncate. Second pair of gland pores within striated integument between AE

Figure 4  Linodatalacarus billabongis sp. nov., female: A, leg I, medial aspect; B, leg II, medial aspect; C, leg III, medial aspect; D, leg IV, medial aspect; E, tibia/tarsus II, medial aspect; F, tibia III, medial aspect. (r, remnants of secretion for fixing cocoons) Scale line = 50 μm.
and PE. OC 92 µm long, 51 µm wide (Figure 3A). Plate not divided. Cornea reduced, 2 µm wide, not sharply delimited from surrounding integument. Both pore canaliculus and gland pore within lateral margin of the OC. PD 232 µm long, 132 µm wide, with pair of slightly raised longitudinal costae; their sculpturing same as that of remainder of plate. Anterior margin of plate truncate. Fourth and fifth pairs of gland pores on small platelets within striated integument, fourth pair adjacent to insertion of leg IV, and fifth pair near distal margin of idiosoma, often seen only at ventral aspect. Dorsum with only two pairs of setae, these very short. First pair of setae near anterior margin of AD, the other pair on PD at 0.46 relative to the length of that plate.

All ventral plates fused, this shield 275 µm long. Its integument delicately porose and with a faint reticulation, marginally delicately foveate. Area representing the GA with three pairs of ventral setae and six to seven, rarely up to eight genital acetabula on either side (Figure 3B). Genital sclerites large, with one pair of subgenital setae.

*Gnathosoma* 65 µm long, 58 µm wide, 1.1 times longer than wide (Figure 3C). Rostrum and gnathosomal base almost equal in length. Rostrum triangular. Basal pair of maxillary setae slender, second pair of setae somewhat thicker. Tip of rostrum with two pairs of rostral setae (Figure 3F). Rostrum almost completely closed dorsally; tectum absent. Pharyngeal plate 30 µm long, not reaching basal margin of gnathosoma. Dorsal length of palpal segments P-1 to P-4: 7, 39, 22, and 13 µm respectively. Apical seta of P-2 long and slender; basal seta generally spur-like (Figure 3D and E), in one of the 10 females studied as long as apical seta. Spine of P-3 12 µm long; spine of P-4 21 µm long (Figure 3G).

Legs slender. Leg IV longest; legs I and III almost equal in length. Tibiae and tarsi lack dentiform basiventral processes. Tibiae I and II slightly longer than these legs' telofemora (Figure 4A and B), tibia III 1.7 times longer than telofemur III (Figure 4C), and tibia IV 1.8 times longer than telofemur IV or almost as long as telofemur plus genu IV (Figure 4D). Tarsi with narrow membranes of claw fossa. Leg chaetotaxy, from trochanter to tarsus (parambulacral setae and solenidia included): leg I, 1, 1, 4, 4, 6, 9, 9; leg II, 1, 4, 4, 6, 7, 8; leg III, 1, 2, 3, 4, 7, 6; leg IV, 0, 1, 3, 3, 6, 5. Ventral setae of tibiae I and

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**Figure 5** *Limmohalacarus billabongii* sp. nov.: A, tip of tarsus I, lateral aspect, female (medial setae and claw omitted); B, tip of tarsus I, ventral aspect, female; C, claw of tarsus IV, female; D, genu and tibia IV and two cocoons, medial aspect, female; E, idiosoma, dorsal aspect, deutonymph; F, idiosoma, ventral aspect, deutonymph. Scale lines = 50 µm.
Two new freshwater halacarid mites from Australia

IV smooth; ventromedial seta of tibia II delicately barbed (Figure 4E). Tibia III with two pairs of ventral setae; the two ventrolateral setae slender and smooth, the ventromedial ones spiniform and coarsely bipectinate (Figure 4F). Tarsi I and II with pair of doubled parambulacral setae, tarsi III and IV with singlets. Solenidion on tarsus I 15 µm long, on tarsus II 20 µm long.

Long, slender claws on tarsus I with J-shaped pecten (Figure 5A and B). Pecten with almost 20 tines; tines 10 µm long. Claws on following legs each with lamellar basal process, that process bearing five to six tines (Figure 5C). Pecten of claws J-shaped, tines shorter than those of tarsus I. Tines on claws III and IV wider than those of leg II.

Male
Not seen.

Deutonymph
Idiosoma 288-295 µm long. AD and PD smaller though in outline similar to plates of female. OC separated into large anterior plate with pore canaliculus and triangular posterior plate with gland pore (Figure 5E). Ventral plates AE, PE, GP, and anal plate separate (Figure 5F). AE, PE, GP each with three pairs of setae. GP with 8-10 pairs of genital acetabula. Anal plate with pair of minute anal anal setae.

Gnathosoma as in females.
Legs similar to those of females. Setation of legs; leg I, 1, 1, 4, 6, 6, 9, 9; leg II, 1, 3-4, 4, 6, 7, 8; leg III, 1, 2, 3, 4, 7, 6; leg IV, 0, 1, 2, 3, 6, 5.

Remarks
Limnohalacarus billabongis is characterized by the combination of: idiosoma 300-340 µm long; ventral plates fused to a shield; female genital sclerites with single pair of setae; PD uniformly reticulated, ventral plates finely punctate; OC 1.8 times longer than wide. In the deutonymphs, the OC and the ventral plates are divided; the number of genital acetabula is larger than in females.

Adults of the species from the billabong in the Northern Territory are easily separated from the Western Australian L. australis by the large ventral shield. Juveniles can be separated on the basis of the claws on tarsus I, with numerous long tines in L. billabongis, with few tines but a basal process in L. australis.

Species with a similar ventral shield are L. fontinalis Walter and Bader, 1952, L. lanae Green, 1967, L. mamillatus Bader and Lambrechts, 1984, L. major Bader, 1967, L. major is 450 µm long, L. portmanni 250 µm, hence L. major is larger, L. portmanni smaller than L. billabongis. In contrast to L. billabongis, females of L. fontinalis bear four pairs of setae on the genital sclerites. The OC of L. lanae are shorter (length/width ratio is 1.6) than in L. billabongis, and in L. mamillatus, the marginal areas of the PE but only lateral portions of the PD have a reticulate ornamentation.

The three species L. fontinalis, L. major and L. portmanni are recorded from Central Africa (Walter and Bader, 1952; Bader, 1967, 1968; Green, 1984). L. lanae was taken on Java (Green, 1976) and L. mamillatus found in Belgium in fish aquaria with cichlids (Fain and Lambrechts, 1987).

Biology
The samples are from February, March and June 1983. None of the 36 adult specimens is a male. The females have cocoons or remnants of their stems fixed to the medial flank of tibiae IV (Figure 5D), each cocoon including a single embryo. The ovoid cocoon is approximately 120 µm long, 90 µm wide, its stem 15-45 µm long. In general, both fourth legs of a female bear a similar number of cocoons, from two till a maximum of 8–9 cocoons per leg.

This form of brood-caring seems to be typical in the genus Limnohalacarus (Viets, 1940; Petrova, 1966). Generally, both freshwater and marine species hide their eggs in the substrata inhabited (Teschner, 1963; Kirchner, 1969; Bartsch, 1972).

Key to females of Limnohalacarus
1. Ventral plates AE, PE and GA fused (Figure 3B) ........................................ 2
   Venter with AE, PE and GA separated (Figure 1B) ........................................ 7

2(1). Idiosoma 300-450 µm long ........................................ 3
3(2). Idiosoma 300-400 µm long, OC not divided ........................................ 4
4(2). Female genital sclerites with one pair of sgs ........................................ 5
5 (4). OC slender, at least 1.8 times longer than wide; P-2 with two setae .......... 6
6(5). PD evenly reticulated. Ventral plates delicately punctate but not reticulate .......... 7

Lateral portion of PD reticulate, median portion punctate; ventrolateral portion of ventral shield between insertion of legs III and IV reticulate ...........................
I. Bartsch

Claws on tarsus I with numerous slender tines, tines at least as long as those on posterior claws ................................. 8
Claws on tarsus I posteriorly with few delicate tines, basally with a process (Figure 1G); Female genital sclerites with two pairs of sgs ........................................ 10

8(7). Each of tarsi I-IV with prominent basiventral process. Tines of pectines on tarsi III and IV similar in size, not on processes ........................................ 9
Ventral margin of tarsi I to IV smooth. Basal tines of pectines on tarsi III and IV on processes ......................................... africana

9(8). Anterior AD with small median process. All setae on tibia IV smooth .......... wackeri
Anterior margin of AD evenly rounded. Tibia IV with one bipectinate seta .......... 11

10(7). PD in females slender, more than 1.7 times longer than wide ....................... 11
Length: width ratio of PD about 1.6 ........... inopinatus

11(10). Female genital plate with four pairs of genital acetabula ................. cultellatus
Female genital plate with 8–9 pairs of genital acetabula .................................. australis

ACKNOWLEDGEMENTS

The halacarid mite from Kimberley was collected by S. M. Eberhard and reached me via W. F. Humphreys who also provided information on the collecting area. Collectors of the mites from a billabong in Kakadu National Park were M. Malipatil, J. Fysan and A. Sharley; G. Dally arranged the loan of these mites and sent me collecting data. To all my sincerest thanks.

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The brachiopod fauna of the Plio-Pleistocene Ascot Formation, Perth Basin, Western Australia

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Abstract - Three new species of terebratulide brachiopods Cancellothyris ascotensis sp. nov., Megerlina ireneae sp. nov. and Megerlina dorothyae sp. nov. are described from the Ascot Formation, Perth Basin, Western Australia. The fauna also includes the previously described terebratulid species Anakinctica recta Richardson, 1991 and Anatida gnangarensis Richardson, 1991. The loop of A. gnangarensis is described for the first time. Three further species, Austrothyris grandis (Tenison-Woods 1865), Magellania flavescens (Lamarck 1819) and an indeterminate are also described. The presence of these species in the southwest of Western Australia during the Plio-Pleistocene provides further evidence of the importance of the Leeuwin Current to the distribution of marine invertebrates.

INTRODUCTION

Sediments collected from various bore holes in the Ascot Formation along the coastal plain west of the Darling Scarp in the Perth Basin, Western Australia (Figure 1) have yielded a relatively sparse brachiopod fauna. Richardson (1991) has described two species, Anatida gnangarensis Richardson, 1991 and Anakinctica recta Richardson, 1991 from this fauna. These are redescribed herein. Austrothyris grandis (Tenison-Woods 1865) and Magellania flavescens (Lamarck 1819) are recorded for the first time from the Formation. Three new species, Cancellothyris ascotensis sp. nov., Megerlina ireneae sp. nov. and M. dorothyae sp. nov. are described. A species of indeterminate genus is also described. This is the earliest record of the genus Megerlina and of Magellania flavescens from Australia.

Geology

The Ascot Formation consists of 'fine to very coarse, grey to yellow-brown quartz sands with subordinate carbonate and less frequently quartzose calcarenites' (Kendrick et al. 1991). These generally fine upwards and contain well preserved marine invertebrates including the brachiopods described below. Some bones, teeth and phosphatic nodules have been reworked from the underlying Osborne Formation (Kendrick et al. 1991). The lateral extent of the formation in any direction is unknown.

Kendrick et al. (1991) interpreted the formation as 'representing a sequence of depositional events along the neritic inner shelf, associated with a progressively prograding shoreline.' The age of the Formation decreases from east (Late Pliocene) to the west (Early Pleistocene) (Figure 2). The Ascot Formation overlies the Albian-Cenomanian Osborne Formation unconformably and is separated by minor transitional units (Balme 1980) from the overlying Bassendean Sands and Guildford Formation (Low 1971; Playford and Low 1972). There was a major regression at the end of the Ascot Formation deposition (Kendrick et al. 1991).

The two members of the Ascot Formation can be separated biostratigraphically by the molluscs present. The older eastwards Ascot assemblage contains the arcoid bivalve Cucullaea and the janthinid gastropod Hartungia confirming the age as Pliocene (Kendrick et al. 1991). Neither of these two genera are found in the younger westwards member of the formation and it is regarded as Early Pleistocene (Kendrick et al. 1991). Planktonic foraminifera from the older member are regarded as Pliocene in age (Mallett 1982). Mallett (1982) also suggested that the temperature during deposition was similar ("neither significantly colder, at least as warm") to that presently experienced along the south western margin of Australia. The presence of phosphatic nodules, quartz sand and the lack of carbonate deposits suggests that the temperature may actually have been much cooler than at present (McNamara, personal communication). The brachiopods herein described occur in both the Pliocene and Pleistocene deposits with some overlap as mentioned below.

METHODS AND MATERIAL

The specimens examined have been primarily
R.S. Craig

Figure 1 Extent of the Ascot Formation in the Perth Basin, Western Australia.

collected by G. W. Kendrick, J. G. Hastings, V. A. Ryland and a number of others including J. Neil, F. Page, E. O'Driscoll, F. Iley, B. R. Wilson, L. J. Gray and A. D. Allen and K. Morgan from the Geological Survey of Western Australia. The specimens are housed in the Western Australian Natural History Museum Collection. The specimens were all measured to an accuracy of 0.1 mm using digital calipers. Specimens were coated with ammonium chloride whitening agent prior to photography.

SYSTEMATIC PALAEONTOLOGY
Phylum Brachiopoda Dumeril, 1806
Subphylum Rhynchonelliformea Popov, Bassett, Holmer & Laurie, 1993

Order Rhynchonellida Kuhn, 1949
Suborder Terebratellidina Muir-Wood, 1955
Superfamily Terebratuloidea Gray, 1840
Family Cancellothyrididae Thomson, 1926
Subfamily Cancellothyridinae Thomson, 1926
Genus Cancellothyris Thomson, 1926

Type Species
Terebratula cancellata Koch, 1843.

Cancellothyris ascotensis sp. nov.
Figure 5 H–L

Diagnosis
Non bifurcating costae; incipient folding; narrow symphytium; rectangular socket teeth.

Material Examined
Holotype
WAM 86.1606 Jupp’s Bore, West Gingin, Ascot Formation, Perth Basin, Late Pliocene.

Paratypes
WAM 78.172, 590, 1147, 3117 Paulik’s Bore, Jandakot, Ascot Formation, Perth Basin, Early Pleistocene.

Description
External. Shell small to medium-sized, 2.2 to 15.3 mm long. Pyriform. Biconvex. Width greatest anterior to mid-length, 75% of shell length. Surface capillate (6 ribs per mm at mid-length), not bifurcating. Costae increasing in number after each major growth line. Ridges wider than troughs. Finely and densely punctate. Cardinal margin curved; lateral margin convex with respect to ventral valve; anterior commissure incipiently paraplicate (shell distorted). Umbo short, beak suberec, slightly labiate. Foramen mesothyridid, large (13% of shell length). Palintrope and symphytium very narrow. Deltidal plates conjunct, triangular, meeting at apex.

Dorsal Valve. Outer socket ridge thin. Sockets a narrow trench. Inner socket ridge thin and joins upward curved outer hinge plate. These are fused with crural base. Cardinal area very delicate, wide, with little thickening towards lateral margin. Cardinal process small, subcircular striated cup, 7% shell length.

Remarks
The lack of bifurcation of the ribs is significant in
Figure 2 Division of the Pliocene and Pleistocene sections of the Ascot Formation in the Perth metropolitan area, Perth Basin, Western Australia (adapted from Kendrick et al. 1991).

this species. There is an increase in number of ribs and these appear after each of the major distinct growth lines. There is no indication of bifurcation of individual ribs.

Richardson (1971) placed Terebratulina flindersi Chapman, 1913 and Terebratulina scoulari Tate, 1880 in the genus Cancellothyris. This is accepted here as the deltidal plates on these species are conjunct whereas in Terebratulina they are disjunct. The new species differs from C. flindersi described from Mallee Bore of Late Eocene age in South Australia, in that it is longer, lacks bifurcation of the ribbing and lacks spines at the lateral margins (Chapman 1913). C. scoulari described from the Late Oligocene to Early Miocene of South Australia (Tate 1880) differs in that the socket teeth are tapered in contrast to the rectangular teeth in C. ascotensis. Moreover, it has a clear deep sulcus which is lacking in C. ascotensis and the ribs repeatedly bifurcates which does not occur in C. ascotensis. C. hedlei (Finlay 1927) is a recent species described from southern Australian and South Pacific waters (Foster 1989). It has a wide symphytium, unlike the narrow symphytium of C. ascotensis. It also has bifurcating costae and a clear sulcus in the dorsal valve, features not found in C. ascotensis. C. platys Brunton and Hiller, 1990 is a recent species described from the western coast of South Africa. It is very similar to C. ascotensis but is larger and has a well developed pedicle collar which is free anteriorly. C. ascotensis has a narrow sessile pedicle collar. An undescribed extant Cancellothyris from Dunsborough, Western Australia also lacks bifurcating costae but has a wider symphytium, a
rectangular foramen and is more labiate than *C. ascotensis*.

**Etymology**
This species is named after the Ascot Formation.

**Superfamily** Terebratelloidea *King*, 1850  
**Family** Terebratellidae *King*, 1850  
**Subfamily** Anakineticinae *Richardson*, 1991  
**Genus** *Anakinetica* *Richardson*, 1987

**Type Species**  
*Terebratella citmingii* *Davidson*, 1852.

*Anakinetica recta* *Richardson*, 1991  
Figure 3 A–E  
1991 *Anakinetica recta* *Richardson*: 33, figure 1. G–L.

**Material Examined**

**Holotype**  
WAM 90.241 Paulik’s Bore, Jandakot, Ascot Formation, Perth Basin, Early Pleistocene.

**Paratypes**  
WAM 90.242-246 Paulik’s Bore, Jandakot, Ascot Formation, Perth Basin, Early Pleistocene.

**Other Material**  
Ascot Formation, Perth Basin, Late Pliocene:  
WAM 81.218 Number 1 Bore, Redcliffe State School; 86.965, 974 Iley’s Bore Number 1; 86.1260, 1414 Iley’s Bore number 2, Banjup; 87.183 Iley’s Bore number 4 bore; 80.1092 Western Mining Corporation, Cataby; 64.5 number 5 bore, Gnangara; 66.918 number 8 bore, Gnangara; 77.921,922 Kando’s Bore number 1; 77.1425, 1653, 1863, 1864, 2077, 2926, 3210 Rando’s Bore number 2, Thornlie; 83.2411 Humfrey’s Bore; 85.1009 Cameron’s Bore; 94.1280 Larsen’s Bore, West Gingin; 74.1008 Gray’s Bore, Gosnells.

Ascot Formation, Early Pleistocene:  
WAM 84.1273 Argentiers Bore, Canning Vale; 86.413 Iley’s Bore, Forrestdale; 67.702 Adrian’s Nursey Bore; 70.997 Schafer’s Bore; 70.1754 Poletti’s Bore; 75.1016,1025 Exploratory Bore; 71.141, 74.176, 376, 816, 76.255, 472, 706, 864, 947, 1081, 1123, 1163, 1223, 1252, 1408, 90.241-246 Paulik’s Bore, Jandakot; 75.807 West Pinjarra.

**Description**

**Exterior.** Shell subcircular to ovate from 1.4 to 12 mm long. Biconvex, depth 35% to 49% shell length, ventral valve deeper than dorsal valve in majority of specimens. Width greatest at or anterior to mid-length; 66% to 98% shell length. Growth lines clearly visible, punctae very fine and dense. Cardinal margin gently curved to nearly straight, distinct umbo in dorsal valve; lateral valve edge bevelled to round, margin concave with respect to ventral valve; anterior valve edge bevelled, anterior commissure unisulcate. Umbo strong; beak truncated, straight to incipiently suberect; beak ridge sharp to gently rounded. Foramen small in large specimens, 3% shell length, permesothyridid. Palintrope high, wide, concave, symphytium straited longitudinally.

**Interior.** Ventral valve. Hinge teeth triangular up curved, grooved at union with lateral margin, heavily buttressed to margin; no dental plates. Pedicle trough narrow between thickened lateral margin walls. Adductor muscle scars short, kidney-shaped, separated by low septum.


**Remarks**

The material studied contained the type specimens and 324 others. The greatest width appears to be at the mid-length in the more elongate specimens but posterior to it in the more sub-circular specimens. The dorsal valves are very convex exteriorly. When standing alone, they are asymmetrically balanced, with the thickened
posterior weighed downwards, the thin anterior upwards. Many specimens are broken towards the anterior where there is no lateral thickening. The concentric growth lines are clearly visible and close together. Curvature of the dorsal valve varies from strongly convex to almost flat. This curvature is not size dependent, as both the larger (up to 12 mm) and the smallest (2 mm) can be deeply curved or nearly flat. Those that are flattest are more sub-circular. The foramen is very small and does not change size greatly with ontogeny being 15% (0.3 mm diameter) of shell length in small specimens and 3% (0.4 mm in diameter) of shell length in the largest. The beak ridges are roundly sharp, and the beak gives the appearance of being notched where the foramen cuts the ridge. The specimens range over both the older and younger Ascot Formation and thus range from Late Pliocene to Early Pleistocene in age (Kendrick et al. 1991).

Genus Adnatida Richardson, 1991

Type Species

Magasella deformis Tate, 1880.

Adnatida gnangarensis Richardson, 1991

1991 Adnatida gnangarensis Richardson: 41, figure 5A–F.

Material Examined

Holotype

WAM 90.247 Mines Department Bore No 5, Gnangara, Ascot Formation, Perth Basin, Late Pliocene.

Paratypes

WAM 90.248, 249 Mines Department Bore No 5, Gnangara, Ascot Formation, Perth Basin, Late Pliocene.

Other Material

WAM 64.5, 90.247 Mines Department Bore No 5, Gnangara; 73.132 Kowalski’s Bore, Gosnells; 77.1425 Rand’s Bore, Thornlie, Ascot Formation, Perth Basin, Late Pliocene.

Description

Exterior. Shell 2 mm to 20 mm long. Ovate. Biconvex, dorsal valve flatter than ventral valve, depth to 56% shell length. Widest at mid-length or anterior to it, width to 71% shell length. Growth lines numerous, distinct, punctae fine and dense. Cardinal margin relatively narrow to 30% shell length, strongly curved; lateral valve edge rounded, lateral margin sigmoidal; anterior commissure edge bevelled, margin unisulcate. Beak sharp, incurved; beak ridges rounded. Foramen small, 2% shell length, permesothyridid. Symphytium high, triangular, concaved.


Dorsal valve. Outer socket ridges wide. Socket ovate, floor swollen, strongly thickened to valve base. Inner socket ridges fused to swollen crural base and overhanging socket slightly. Septalium indistinguishable from swollen crural bases. Cardinal area united with thin cleavage to septum. Median septum blade like, bifurcates narrowly posteriorly. Crural process high, slightly converging, triangular with sharp point. Loop 71% of shell length, teloform (Magellaniiform) and terminates just posterior to anterior commissure, covered in calcite crystals. Connection with septum obscured. Anterior adductor muscle scars large elongate, either side of median septum.

Remarks

The genus Adnatida has also been described from the Eocene of South Australia (Richardson 1991). All specimens of Adnatida gnangarensis came from bores of Late Pliocene in age (Kendrick et al. 1991). One specimen has a deep cleft antrectolaterally primarily on the ventral valve resulting in a “dimple”. This may be the result of differential growth after attack or due to being “squeezed” between substrate elements.

Subfamily Terebratellinae King, 1850

Genus Austrothyris Allan, 1939

Type Species

Waldheimia gambiaensis Thomson, 1918.

Austrothyris grandis (Tenison-Woods, 1865)

1865 Waldheimia grandis Tenison-Woods: 2, plate I, figure A–F.

1876 Waldheimia gambiaensis R. Etheridge junior: plate II, figures 4 a–d.


1927 Magellania grandis: Thomson: 301.

Figure 4  A–F, *Austrothyris grandis* (Tensin-Woods, 1865). A, WAM 76.1038a, dorsal valve interior x 3.5; B: WAM 76.1038b, dorsal valve interior x 3.5; C, F, WAM 71.887a. C, dorsal valve interior; F, dorsal valve exterior. Both x 2.5.D: WAM 76.1038c, dorsal valve interior x 3.5; E: WAM 76.1038d, ventral valve interior x 3.
Material Examined
WAM 86.1605 Jupp's Bore, West Gingin; 73.179 Kowalski's Bore, Gosnells, Ascot Formation, Perth Basin, Late Pliocene.
WAM 71.887 Thompson Lake; 73.179 Kowalski's Bore, Gosnells, Ascot Formation, Perth Basin, Late Pliocene.
WAM 71.887 Thompson Lake; 73.220 Australind; 76.256, 948, 949, 1038, 1040, 77.3798, 78.2775 Paulik's Bore, Jandakot; 72.1388, 1728, 2054, 2056, 2267 Cement Works Bore, Jandakot, Ascot Formation, Perth Basin, Early Pleistocene.

Description
Exterior. Incomplete specimens, shell medium-sized (greatest part 22 mm long). Biconvex. Smooth, growth lines distinct, finely and densely punctate. Cardinal margin curved with deeper curve under umbo. Umbo stout; beak straight to slightly suberect; beak ridges rounded. Foramen large (18% of greatest length available), mesothyridid, circular, beveled. Deltidal plates conjunct; palintrop narrow, convex; symphytium striated horizontally, ridges on either edge.

Interior. Ventral valve. Pedicle collar sessile, complete, does not extend into valve. Hinge teeth roundly rhombic, pointing posteriorly, leading edge slightly curved, concave, flush with lateral margin, no dental plates and bases not swollen. Adductor muscle scars kidney-shaped depressions either side of a low ridge.

Remarks
Although the median septum does not appear to run fully into the septalum, there is a small ridge half way into the septalum in some specimens. This may be consistent with either the median septum or the cardinal process support. The specimens are consistent with the descriptions of A. grandis in all other respects. Austrothyris grandis was described from the Early Miocene of South Australia (Allan 1939). A small specimen (3.3 mm long) has a clear septalum and the septum rises at the anterior end which is just anterior to the midline. The deltidal plates are disjunct at this stage.

Genus Magellania Bayle, 1880

Type Species
Terebratula flavesens Lamarck, 1819.

Magellania flavesens (Lamarck, 1819) Figure 5 A-G
1819 Terebratula flavesens Lamarck: 246.
1819 Terebratula dentata Lamarck: 246.
1835 Terebratula australis Quoy and Gaimard: 551, plate 85 figures 1–5.
1835 Terbratula recurva Quoy and Gaimard: 554, plate 85, figures 10–11.
1847 Terebratula spadae Aradas: 237.
1850 Waldheimia australis: King: 145, plate 20, figures 10–12.
1852 Waldheimia flavesens: Davidson: 64, figures 6–7.
1860 Terebratula (Waldheimia) flavesens: Reeve: plate 1.
1876 Waldheimia flavesens: Tenison-Woods: 57.
1880 Waldheimia flavesens: Davidson: 41, plate 3, figures 10–12.
1880 Magellania flavesens: Bayle: 240.

Figure 5 A–G, Magellania flavesens (Lamarck, 1819). A, WAM 76.257a, dorsal valve interior x 4; B: WAM 77.2675, dorsal valve interior x 4; C, WAM 76.257b, ventral valve interior x 5; D, WAM 76.257c, dorsal valve interior x 5; E–G, WAM 78.3116, E, lateral view; F, anterior commissure; G, dorsal valve view. All x 4. H–L, Cancellothyris ascotensis sp. nov. H–L, WAM 86.160a holotype. H, dorsal valve interior x 3; I, ventral valve interior x 3.5; J, dorsal valve exterior x 3.5; K, ventral valve exterior x 3.5; L, anterior commissure x 3.5. M–R, Megerlina irenae sp. nov. M–O, WAM 86.160, holotype. M, dorsal valve view; N, lateral view; O, holotype, anterior commissure. All x 7; P, WAM 70.1629, paratype, dorsal valve interior x 7; Q, WAM 86.1604, paratype, ventral valve interior x 7; R, WAM 70.1629b, (SEM) ventral valve interior x 17. S–U, Megerlina dorothiae sp. nov. S–U, WAM 71.1536, S, dorsal valve exterior x 8; T, dorsal valve interior x 8; U, dorsal valve exterior x 20.


1974 *Magellania flavescenes*: Foster: 123–125, plate 11, figure 8, plate 19, figures 5–16, plate 23, figures 5–5, text figure 3 part 25, text figure 31. C-D

Material Examined

WAM 71.1537 Bushell's Bore, Kewdale, Ascot Formation, Late Pliocene.


WAM 86.277 Buanyup drain, Vasse, Perth Basin, Middle Holocene.

**Material Examined**

**Family Kraussinidae Dali, 1870**

**Genus Megeriina Deslongchamps, 1884**

**Type Species**

*Kraussia lamarckiana* Davidson, 1852.

*Megeriina irenae* sp. nov.

Figure 5 M-R

**Material Examined**

**Holotype**

WAM 86.1604a, Jupp’s Bore, West Gingin, Ascot Formation, Perth Basin, Late Pliocene.

**Paratypes**

WAM 86.1604b, Jupp’s Bore, West Gingin, Ascot Formation, Perth Basin, Late Pliocene.WAM 70.1629a and b, 70.1409, 78.2774, 4062, 79.507 Paulik’s Bore, Jandakot Ascot Formation, Perth Basin, Early Pleistocene.

**Other Material**


WAM 76.1478, 78.2774, 3469, 4063, 79.263, 378, 1081 Paulik’s Bore, Jandakot.

**Diagnosis**

Shell wider than long; costae not bifurcating; dorsal valve with wide sulcus; ventral valve with medial ridge;

**Description**

*Exterior.* Shell small to medium-sized, 3 to 12 mm long (largest specimens incomplete). Subtriangular to ovate. Biconvex, dorsal valve flatter than ventral valve Widest anterior to mid-length. Finely and densely punctate, punctae oval. Shell ribbed, extending from posterior margin; ribs wide, 6% of shell length, troughs as wide as ribs, some ribs bifurcate anterior to mid-length. Dorsal valve sulcus anterior to mid-length. Cardinal margin strongly curved; lateral margin convex towards ventral valve, crural base and inner hinge plates fused. Vertical ribbing exists along union of inner socket ridge with outer hinge plate. Crural base extends posteriorly as slight rise. Crura divergent. Inner hinge plates join bifurcating median septum in cardinal third of posterior section. Median septum extends just beyond mid-length; crest to base thin, not swollen. Septalium, sockets and cardinal process form a platform over posterior section of valve. Cardinal process with protruberant lip, projects towards ventral valve, trilobed, lamella parallel to trilobed edge producing folded pattern. Loop incomplete.

**Remarks**

The disjunct deltidal plates are not characteristic of the genus. Richardson (1994) says the deltidal plates are “invariably conjunct”. However, Bitner (1996) illustrated a disjunct specimen of *M. antarctica*. The fusion of the plates may well be a feature of later ontogeny. Unfortunately no specimens of large ventral valves or cojoined valves are available. The species is known from the present day waters of south eastern and south western Australia. This is the earliest record of the species.
sulcus 30% shell length. Umbo short, wide; beak subrect; beak ridges sharp. Foramen large, 21% shell length, mesothyridid. Deltidal plates present, disjunct. Pseudodeltidium concaved.

**Interior.** Ventral valve. Hinge teeth rectangular, converging towards dorsal valve, sharp on upper margin with swollen bases. Pedicle collar extends width of umbo, striated vertically. Median rise extending from posterior to mid-length. Shell thin, translucent and punctae clear.

Dorsal valve. Hemispherical and very deep. Outer socket ridge indistinct from lateral margin. Inner socket ridges upcurved forming the roof of socket. Socket cylindrical, slight with slight swelling at base of sockets. Cardinal process indistinct from posterior margin. Socket ridges and cardinal process curve towards valve floor meeting at bifurcating median septum to form thin shallow septalium. Median septum extends two thirds of shell length from the posterior margin then rises up anteriorly to bifurcate into two diverging processes.

**Remarks**

*Megerlina irenae* differs from *M. pismum* (Lamarck 1819) found in the waters off the eastern coast of South Africa in possessing a median ridge in the ventral valve, a feature lacking in *M. pismum* (Hiller 1986). *M. levis* Hiller, 1979, described from the Late Pleistocene deposits on the Zululand coast, lacks any radial ornamentation (Hiller 1979). *M. davidsoni* (Velain, 1877) described from shallow water, St Paul Island in the Southern Ocean differs from *M. irenae* in having a longer beak, a narrower sulcus (Cooper 1981) and lacking the median ventral ridge found in *M. irenae*. Cooper (1973) also described an extant species of *Megerlina* from the Southern Ocean. This species has outer hinge plates which are concave, thick and unite with the median septum (Cooper 1973), unlike *M. irenae*. Moreover it does not have the median ridge present in the ventral valve found in *M. irenae*. *M. striata* Jackson, 1952, an extant species from the Cape of Good Hope, is large attaining 14.1 mm in length. The ribs are bifurcate and the socket ridges are stout (Jackson 1952). This differs from *M. irenae* which is small (up to 4 mm), with ribs that do not bifurcate and slender socket ridges, the outer ridge indistinguishable from the lateral margin. *M. capensis* (Adams and Reeve 1850) an extant species also from the Cape of Good Hope is twice the size of the largest *M. irenae*, is longer than wide and has bifurcating costae (Jackson 1952). *M. lamackiana* (Davidson 1886–88) an extant species described from Port Jackson, New South Wales, has a wide hinge plate lacking in *M. irenae*.

**Etymology**

The species is named in honour of my wife Irena.

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**Material Examined**

**Holotype**

WAM 71.1536 Bushell's Bore, Kewdale, Ascot Formation, Perth Basin, Late Pliocene.

**Diagnosis**

Small *Megerlina* without costation, thickened sockets, shell thickened, large depression for muscle scars.

**Description**

**Exterior.** (Dorsal valve only). Shell small to 2 mm long by 2.5 mm wide. Convex with medial sulcus. Finely punctate; growth lines distinct with no costation. Cardinal margin nearly straight. Shell relatively thick.

**Interior.** Outer socket ridges thick. Inner socket ridges curved upwards to form incomplete socket roof. Shell thickened laterally along socket area. Median septum bifurcates posteriorly forming a narrow septalium. Septum rises anteriorly and bifurcates. Laminar on either side of septum. Interior margin of shell slopes away from septum. Two large (50% shell length) anterior adductor muscle scars either side of septum posteriorly. Median septum and muscle scars in a thickened walled depression, 70% shell length. Cardinal process insignificant.

**Remarks**

This single specimen is similar to *M. irenae* in general shape. However, it lacks costation, as does *M. levis* Hiller, 1979, but the sockets are comparatively thicker and the overall thickened shell and depression housing the septum and muscle scars is distinctive.

**Etymology**

Named in honour of my mother Dorothy.

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**THE SIGNIFICANCE OF THE BRACHIOPOD DISTRIBUTION IN THE PERTH BASIN**

The distribution of the Cenozoic brachiopods in the Perth Basin is summarised in Table 1. The most abundant species collected is *Anakinetta recta* Richardson, 1991, which comprises some 73% of the total number of specimens. *A. recta*, *Austrothyrus grandis*, *Cancellothyris ascotensis* and *Megerlina irenae* have been found in both the Late Pliocene and Early Pleistocene sections of the Ascot Formation (Kendrick *et al.* 1991). *Magellania flavescens* is also found throughout the Ascot Formation, and also extends into the Holocene. It's distribution pattern indicates a greater frequency in the Early
Table 1 Distribution of species in the Cenozoic deposits of the Perth Basin shown as a percentage of all brachiopod specimens found.

<table>
<thead>
<tr>
<th>Species</th>
<th>Late</th>
<th>Early</th>
<th>Holocene</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Pliocene</td>
<td>Pleistocene</td>
<td></td>
</tr>
<tr>
<td>Aiiakinetica recta</td>
<td>24.90</td>
<td>48.11</td>
<td></td>
</tr>
<tr>
<td>Adnatida guangarensis</td>
<td>7.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australothyris grandis</td>
<td>1.32</td>
<td>5.28</td>
<td></td>
</tr>
<tr>
<td>Magellania flavescens</td>
<td>0.38</td>
<td>5.66</td>
<td>0.18</td>
</tr>
<tr>
<td>Cancellothyris ascotensis</td>
<td>1.32</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>Megerlina irenae</td>
<td>0.38</td>
<td></td>
<td>3.39</td>
</tr>
<tr>
<td>Megerlina dorothyae</td>
<td>0.18</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pleistocene than in the Late Pliocene. This is the only species described from the Ascot Formation that is extant. *Megerlina dorothyae* and *A. guangarensis* have only been recorded from the Late Pliocene. *A. recta*, *A. grandis*, and *M. irenae* are all more prevalent in the Early Pleistocene than in the Late Pliocene. *C. ascotensis* is more prevalent in the Late Pliocene than in the Early Pleistocene. Larger specimens tend to be very poorly preserved, many being broken, and shell pieces confused with those of bivalves. This may have implications in the diversity percentages.

*Australothyris grandis* was described from the Early Miocene of South Australia (Allan 1939) and is present in the Early Miocene Abrakurrie Limestone of the Eucla basin, Western Australia. The genus *Adnatida* has been described from the Eocene of South Australia (Richardson 1991). The genus *Anakinetica* has been described from the Late Oligocene of Victoria, the Early Miocene of Victoria and South Australia (*A. breva*) and the Pliocene of Victoria (*A. tumida*) (Richardson 1991). *A. breva* is also present in the Early Miocene Abrakurrie Limestone of the Eucla Basin, Western Australia. The presence of genera common to earlier formations in southern Australia suggests that the oceanic temperatures during the Late Pliocene and Early Pleistocene of the Perth Basin were possibly similar to those in the Eucla, St Vincent and Otway Basins which ranged from 14°-19° (James and Bone 1991). However, the presence of phosphatic nodules in the Ascot Formation suggests the temperature was cooler than the southern Australian basins mentioned above. This, with the presence of genera *Austrothyris*, *Adnatida* and *Anakinetica* in the Ascot Formation, Perth Basin can best be explained by a hiatus in the Leeuwin Current. Cooler waters moving south to north with no interruption from the southerly flowing Leeuwin Current could have possibly allowed for the northward migration of the genera.

Brachiopods appear to be less influenced by temperature than by substrate (Richardson 1997). *Anakinetica breva* and *Adnatida deforms* are found in bryozoal limestone deposits whereas the Ascot Formation consists of 'fine to very coarse, grey to yellow-brown quartz sands with subordinate carbonate and less frequently quartzose calcarenites' (Kendrick et al. 1991). This may account for the difference in the species.

*Magellania flavescens* could have evolved on the western coast of Australia and the have been dispersed in an easterly direction, to appear along the southern coast in Recent times. The mechanism for this distribution would most likely be the Leeuwin Current which is known to have been influential in the distribution of echinoids (McNamara 1999) and large warm water foraminifera (McGowran et al. 1997).

The reduced number of specimens compared to other deposits may be due to temperature, but as mentioned, temperature is not believed to have been a limiting factor (Richardson 1997). Kendrick (pers comm) suggests that the Ascot Formation is shallow inshore shelf with several regressive episodes indicated. This is believed to have been a high photic zone with seagrasses. This is supported by the presence of the bryozoan *Densipora*. Large seagrass attaching foraminifers are conspicuously absent, possibly because of the lower temperature which is suggested by the presence of phosphate nodules. The lack of significant numbers of brachiopods may therefore be due to a higher light intensity than would normally allow them to proliferate.

ACKNOWLEDGEMENTS

I am indebted to the assistance given by Dr K. J. McNamara and the Western Australian Museum for the preparation of this paper. I would also like to thank Mr G. W. Kendrick who provided bore material to be examined and provided important stratigraphical information, and Dr C. J. S. deSilva for his assistance with figures 1 and 2 and valuable comments on this paper.

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*Manuscript received 6 April 1999; accepted 17 September 1999.*
Occurrence of *Acetes sibogae* Hansen (Crustacea: Decapoda: Sergestidae) in Western Australia, with notes on the northern Australian population

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Shrimps of the sergestid genus *Acetes* (Decapoda, Sergestidae) are distributed mainly in estuaries and coastal waters of the tropical and subtropical regions of the world (Omori 1975, 1977; Xiao and Greenwood 1993). Nevertheless, no record has been obtained from the subtropical eastern Indian Ocean.

Recently, many specimens of *Acetes* were collected at a site in the Swan River near Perth, Western Australia. They resemble to the Australian form of *A. sibogae* Hansen, 1919, described originally as *A. australis* by Colefax (1940) from the east coast. Further analysis of these specimens and comparison with northern Australian specimens indicated that the Western Australian population belongs to *A. sibogae*.

This record is the new addition to the Western Australian fauna and is a range extension of the genus.

In the synonymy, only the important and relevant literature has been listed. Abbreviations used in the text are: cl, carapace length in millimetres; NTM, Northern Territory Museum, Darwin; WAM, Western Australian Museum, Perth.

**Acetes sibogae** Hansen, 1919  
Figures 1, 2


*A. australis* Colefax, 1940: 345, figures 1–19a.


**Material Examined**

**Australia**: Western Australia: 61 males (2.5–4.6 mm cl), 29 females (2.5–5.8 mm cl), 3 inds (damaged), Coode Street Jetty, Swan River, Perth, WA, 4 Feb 1998, coll. D. Bloch (WAM C 23140).

Northern Territory: numerous males and females (2.1–4.5 mm cl), Caimen Creek, Port Essington, NT, low water, 4 May 1982, coll. and det. A. J. Bruce (NTM Cr. 004936).

**Remarks**

The taxonomic status of *A. sibogae* s.l. has been subject to considerable debate owing to wide morphological variation within its geographical range (Omori 1975; Ravindranath 1980; Xiao and Greenwood 1993). The species has been occasionally reported under the following names: *S. australis* Colefax, 1940; *A. sibogalis* Achuthankutty and George, 1973; *A. orientalis* Achuthankutty and Nair, 1976.

Omori (1975), in a comprehensive study of this group, relegated the species to subspecies rank within *A. sibogae*, based primarily on the number of falcate hooks (or spines) on the capitulum of the petasma: *A. s. sibogae* represented in south Asian waters, from India to Philippine-Indonesia; *A. s. australis* in eastern Australia; *A. s. sibogalis* in Cochin, India (see also Perez-Farfante and Kenseley 1997). Later, Omori (1977) suggested that the eastern Australian population to be returned to species rank, though a detailed account for this action was not presented formally. Holthuis (1980) accepted Omori’s specific concept.

On the contrary, Ravindranath (1980), after reviewing the data available to him, concluded *A. sibogae* to be a morphologically variable, widely distributed species, having priority over the above species and/or subspecies. Xiao and Greenwood (1993) followed Ravindranath.

In general features, Western Australian specimens (Figure 1) show the greatest affinity to the eastern Australian form, though some minor differences were noticed. To clarify their identity, they were compared with specimens from northern Australia (Figure 2). No morphological data for the latter population are heretofore presented.

The lower antennular flagellum of males normally consists of 12 segments in the specimens from the western and northern coasts of Australia (Figures 1d, 2b). This is consistent with all the *A. sibogae* complex (Omori 1975; Ravindranath 1980).

The structure of the coxa and basis of the third
Figure 1 Acetes sabogae Hansen, 1919, male 4.8 mm (a, c-e) and female 5.8 mm (b, f) from Perth, Western Australia: a, anterior part of body, male; b, same, female; c, petasma; d, male lower antennular flagellum; e, male basis and coxa of third pereopod; f, thelycum.
First record of *Acetes sibogae* in Western Australia

Figure 2 *Acetes sibogae* Hansen, 1919, male 3.6 mm cl (a-d) and female 4.5 mm cl (e) from Port Essington, Northern Territory, Australia: a, male basis and coxa of third pereopod; b, male lower antennular flagellum; c, petasma; d, same, distal part enlarged; e, thelycum.

The pereopod shows some variation among local populations. In Western and northern Australian specimens, the coxa possesses a well-developed inner projection in males and females (Figures 1c, 1f, 2a, e), as also noted in the eastern Australian and some other populations. The Philippines population, on the contrary, has the coxa with a less-pronounced mesial tooth, particularly in males (e.g. Hansen 1919; Omori 1975).

The northern Australian specimens have a well-developed basial projection (Figure 2a, c), projecting most in larger specimens. The toothed basis is common in other populations, but at best forms only an obtuse angle in Western Australian specimens (Figure 1e, f).

The petasma in Western Australian specimens consistently bears a single falcate spine on the capitulum (Figure 1c) as in the eastern Australian population (Colefax 1940; Omori 1975). However, specimens from Malayan waters (Pathansali 1966; Omori 1975) and those from northern Australia show an intermediate form, having a minute secondary spine in addition to the large spine (Figure 2c, d). Males from Philippines and Indian waters have one large and one moderately large falcate spines on the capitulum (Hansen 1919; Omori 1975; Ravindranath 1980). There is a general tendency of the falcate spine to decrease in number towards the south of the distributional range.

Although several populations in different geographical areas can be recognized by a combination of features, the extent of their variation and the limit of their distribution is not precisely defined. Hence, I have considered all forms to belong to *A. sibogae*. The identity of *A. s. sibogalis* still remains tentative, and further study is required.

**Distribution**

*Acetes sibogae* is known to occur from the southwest India to the east and west coasts of Australia, throughout the Philippine-Indonesian region.

**Ecological note**

*Acetes sibogae* has occurred in the Swan River near Perth, at least in summer-early autumn, for the last three years, forming surface swarms during both day and night (A. Sampey pers. comm.; data source D. Block).

The sex ratio is biased toward males, 56 and 68% males in Northern Territory and Western Australian specimens, respectively.
ACKNOWLEDGEMENTS

I thank Diana Jones and Alison Sampey of the Western Australian Museum for giving me an opportunity to report the interesting specimens from Western Australia, Perth, and Karen Coombes of the Northern Territory Museum, Darwin, for providing A. sibogae from northern Australia. I am grateful to Vicki Wadley of the CSIRO Marine Research, Hobart, for reading the manuscript. Thanks are also extended to referees of the journal for their help to improve the paper.

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The distribution of Australian cave fishes

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INTRODUCTION

Worldwide only 84 species of fish are known to occur in hypogean waters with 13 instances of two species and three instances of three species occurring in sympatry (Proudlove 1997; G.S. Proudlove, pers. comm. 1999). Two species of blind cave fish are known from Australia, namely the Blind Gudgeon, *Milyeringa veritas* Whitley, 1945 (Perciformes: Gobiidae) and the Cave Eel, *Ophisternon candidum* (Mees, 1962) (Synbranchiformes: Synbranchidae). They are found in sympathy on the Cape Range peninsula of northwestern Australia. Both species are listed as endangered under Western Australian fauna legislation. This note presents the known occurrence of these cave fishes and includes a major range extension of *M. veritas* to Barrow Island.

Two primary sources deal with the distribution of the stygofauna (obligate subterranean aquatic species) on the Cape Range peninsula (Mees 1962; Humphreys and Adams 1991). In 1959 Mees (1962) collected widely along the west coast of the peninsula but found stygofauna only in Milyering (C-24; Australian Karst Index number), Kudamurra Well (C-25) and Tantabiddi Well (C-26) and recorded *M. veritas*, *O. candidum*, and *Stygicaris* spp. (Decapoda: Atyidae). Humphreys and Adams (1991) compiled the distributional data then available but recorded no further taxa of stygofauna. An unpublished report (Humphreys 1994) provided further distributional records and information on the habitat, feeding and associated stygofauna.

Distribution of cave fishes

The known occurrences of the two species are shown in Figure 1. Only at C-26 (Tantabiddi Well, location 4 in Figure 1) does *O. candidum* occur in the apparent absence of *M. veritas* (the site ‘South of Yardie Creek’ in Table 1 is of unknown status). The area shown in Figure 1 has been sampled widely for stygofauna (Pesce et al. 1996: Fig. 29) and all the available access points have been sampled in the northern part of the Cape Range peninsula and Barrow Island (W.F. Humphreys, unpublished). In addition, the lower Robe and Fortescue River aquifers, on the mainland opposite Barrow Island, that contain elements of the Cape Range and Barrow Island stygofauna have been sampled widely (W.F. Humphreys, unpublished).

The number of sites from which *M. veritas* has been recorded has increased steadily over time (Table 1: bottom line) and there is still an upward trend in comparable data for *O. candidum*. However, a number of access sites have been lost in the interval from infilling (Table 1: C-361, AB5, Site D), drying (C-282, C-362) or siltation (C-23), and a number of sites are close to planned developments (C-25, AB5), are within periurban areas (C-23, C-27, C-105, C-282, C-361, C-452, C-495, WC 15, WC 44), or in an unmanaged military area (C-28, C-506, C-507). While there has been a significant extension of the range of *M. veritas* to Barrow Island, the inclusive known range of the two species on the Cape Range peninsula has not increased since 1991 (Humphreys and Adams 1991), but there has been considerable infilling of the distribution. These additional sites have markedly increased the known range of habitats and water types inhabited by the fishes.

The fishes are known to be part of a rich stygofaunal community (Table 1; Bradbury and Williams 1997; Humphreys in press a) that contains a number of eco-geographic relicts and phyletic relics with tethyan affinities (Humphreys 1993, 1994, in press; Knott 1993; Danielopol et al. in press), including the only member of the class Remipedia (*Yager and Humphreys 1996*) and the order Thermosbaenacea (*Poore and Humphreys 1992*) in the southern hemisphere with closest affinities with fauna found in caves on either side of the North Atlantic.

The fishes are found close to the coast and up to 4.3 km inland in a predominantly anchialine system, namely there is a fresh to brackish water lens overlying a seawater wedge (Allen 1993) that is affected by marine tides (Yager and Humphreys 1996; Humphreys in press b). *Milyeringa veritas* occurs in waters ranging from fresh to seawater and has been sampled from caves at water depths up to 33 m, from anchialine pools, from wells and from bores in which the water table was up to 50 m below the ground surface. Numbers of *M. veritas* seen in caves vary from few to about 100. *Ophisternon candidum* has been seen in wells and caves, usually singly, occasionally in pairs, and on
Table 1  The known occurrence of the blind cave fish on the Cape Range peninsula and Barrow Island. a, recorded in Humphreys and Adams (1991); b, from field notes of American Museum of Natural History; Station 60, 5 April 1969, c, 1993, d, samples (WAM: P.5863.001) were collected from Neds Well in 1963 but it has not contained water since at least 1987, e, new well south of Yardie Creek (Allen 1982). Commonwealth of Australia land controlled by the Royal Australian Navy (RAN) or the Royal Australian Airforce (RAAF). CRNP, Cape Range National Park. Most of the pastoral wells were located on or adjacent to traditional watering places and a number of the caves were also traditional watering places. 1 Moes (1962), 2 Humphreys and Adams (1991) 3 Humphreys (1994).

<table>
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<th>Index #</th>
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Total sites now (in 1962; 1991; 1994) — *Milgirina veritas* 25 (2, 11, 18) — *Ophisternon candidum* 11 (2, 6, 11)
only one occasion with three together. Many of the cave fish sites are also type localities (Table 1) for other cave restricted species, some of which are prey of the fish (Humphreys and Feinberg 1995).

The population of *M. veritas* — nor *Stygiocaris stylifera* Holthuis — is not genetically uniform and there is evidence of restricted gene flow on the peninsula (Humphreys and Adams 1991). Hence, the presence of the fauna within Cape Range National Park does not in itself provide an adequate representation of the genetic diversity of the fish, nor does it adequately represent their habitat diversity.

ACKNOWLEDGEMENTS

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Revisions of genera in the Asteron-complex (Araneae: Zodariidae).
The new genera Cavasteron and Minasteron

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Abstract - For the Zodariidae of Australia the new genera Cavasteron and Minasteron are erected. Both genera are characterised by the presence of a large terminal palpal claw in both sexes. They differ by the raised cephalic area and the small anterior eyes in Minasteron whereas the profile is low flat and eyes are subequal in Cavasteron. The type species of the latter genus is C. crassicalcar sp. nov. (male, female) and it is further represented by 11 new species: C. agelenoides (male, female), C. atriceps (male), C. exquisitum (male), C. guttulatum (male), C. index (male), C. lacertae (male), C. margaretae (male), C. martini (male), C. mjoebergi (male), C. teniscalcar (male) and C. triunguis (male, female). The type species of Minasteron is M. minusculum sp. nov. The genus is further represented by the new species M. perfoliatus (male, female) and M. tangens (male). Both genera represent a small part of the Asteron-complex as defined by Baehr and Jocqué (1996). They form the crassicalcar-clade, named after the type species of Cavasteron in the cladogram presented there.

INTRODUCTION
The genus Asteron was erected by Jocqué (1991) to accommodate two species, A. reticulatum, the type species, and A. mas, with quite different palps. Already at the time of the initial description, it was established that the genus, which will here be considered as a group of genera, is very speciose and many of its species awaited description. Baehr and Jocqué (1996) estimated that more than 100 species belong to the group and provided a preliminary cladistic analysis. According to Baehr and Jocqué’s analysis, the genus can be divided into 13 groups. It is intended to give some of these groups the status of genera. Not only are they quite well separated but most of the groups are speciose. Hence, Asteron, which would have become a huge and heterogeneous, albeit apparently monophyletic taxon, is divided.
The present paper is the third in a series designed to create new taxa at the generic level to accommodate the many species belonging in the Asteron-complex (see Baehr and Jocqué, in preparation).

MATERIAL AND METHODS
The format of the descriptions follows Jocqué and Baehr (1992). All measurements are in mm.
Abbreviations for the characters:
BA base of embolus
E embolus
CD copulatory ducts
CO copulatory opening
DTA dorsal tegular apophysis
F flange on cymbium
FA frontal appendage of base of embolus
Fe Femur
Mt Metatarsus
P prong
Pa Patella
PC palpal claw
PE prolateral extension of DTA
RE retrolateral extension of DTA
S spermatheca
SP sperm duct
T Tibia
Ta Tarsus
Institutions from which material was borrowed are abbreviated as follows:
AMS: Australian Museum, Sydney (M. Gray)
ANIC: National Museum Canberra (R. Halliday)
CAS: California Academy of Sciences, San Francisco (W. Pulawski, D. Ubick and C. Griswold)
KBIN: Koninklijk Belgisch Instituut voor Natuurwetenschappen (L. Baert)
MAGNT: Museum and Art Gallery Northern Territory (G. Brown)
NHRS: Naturhistoriska Riksmusset, Stockholm (T. Kronestedt)
NMV: Victoria Museum, Melbourne (C. McPhee)
QM: Queensland Museum, Brisbane (R. Raven)
**SYSTEMATICS**

*Cavasteron* gen. nov.

**Type Species**

*Cavasteron crassicalcar* sp. nov.

**Diagnosis**

Representatives of *Cavasteron* are recognised by the presence of a large, terminal palpal claw in both sexes. Further diagnostic characters shared with *Minasteron* are from the male palp: the dorsolateral apophysis is bifid, the ventrolateral one is connected by a dorsolaterally flattened ridge to the body of the tibia; the cymbium has a proximal, retrolateral lobe. *Cavasteron* differs from *Minasteron* by the lower profile of the carapace, the subequal eyes, the virtually quadrangular MOQ, the fewer spines on the anterior tibiae, the posterior tarsal claws which are curved normally and the S-shaped palpal sperm duct.

**Description**

Small to medium-sized spiders (3.00–7.00) with smooth teguments. Carapace widest at level of coxae II, narrowed to 0.65 maximum width in females, to about 0.55 maximum width in males. Profile domed with highest point between fovea and PME (Figure 1a).

Colour: carapace, chelicerae and sternum pale to dark brown; legs and abdomen variable, uniform or with pattern.

Eyes (Figures 1b, c) in three rows (2-4-2). The first row is composed of the ALE, the second of the AME (in the middle) and PLE, the third of the PME. Eyes subequal or ALE smaller than remainder. MOQ roughly quadrangular. Clypeus straight or slightly convex, 3.5 to 6 times the diameter of an ALE; with few hairs. Chilum single, short and wide, with a few or without setae. Chelicerae as usual in the family with a few hairs in front and a dense row on distal promargin; no teeth. Labium narrowed at base; sparsely haired. Endites rather elongate; sparsely haired; with anteromesal scopula. Sternum bulging, more strongly so in males than in females; triangular with straight or slightly procurred anterior margin and slight triangular extensions between coxae. No inter- or precoxal sclerites.

Legs: formula 4123. Spination: few spines on pairs I and II, more numerous on III and IV. Paired tarsal claws (Figures 3c, d) with numerous (12–14) teeth on anterior leg pairs, with slightly fewer on those of legs III and IV. Unpaired claw on a well developed onychium.

Trichobothria in two rows on T, in a single row on Mt and Ta. Hinged hairs present but few, restricted to dorsal side of T. Metatarsal preening brush poorly developed.

Abdomen oval; without sigilla. Spinnerets: AS, long, cylindrical, with very short distal segment; MS and PS very short. Colulus represented by few hairs.

Male palp (Figures 3a, b): tibia with a large lateral concavity delimited by a bifid dorsolateral apophysis and a more or less complex ventrolateral apophysis, most often connected to the main body of the tibia by a dorso-ventrally flattened lamella. Cymbium with large lobe-shaped flange (Figure 21b F), several spines and large distal claw. Embolus with broad base (Figure 21a BA), sometimes with frontal appendage (Figure 21a FA); embolus emerging from retrolateral or posterior part of base; tegulum with large distal apophysis (Figure 21a DTA) consisting of a long, prolateral, gutter-shaped (Figure 21a PE) and a short retrolateral extension ending in a distal pointed part (Figure 21a RE); this spine-shaped extremity is sometimes connected with a ridge to a more proximal, blunt, tooth-shaped prong (Figure 21a P).

Epigyne: external structure simple, with large central copulatory opening (Figure 29b CO); copulatory ducts (Figure 29b CD) starting slightly behind the centre, corkscrew-shaped, running forward then back towards spermathecae (Figure 29b S) near posterior margin. Female palp with strong, conical tarsus with spines on prolateral and ventral sides and large distal claw with a few tiny basal teeth (Figure 29c); claw not turned inward.

**Etymology**

*Cavasteron* is a contraction of Asteron and cavare (Latin for “to dig”).

**Key to the species of Cavasteron**

1. Males .............................................................. 2
   Females .......................................................... 13

2(1). Cephalothorax yellow, or only cephalic area brown, abdomen dorsally pale with dark chevrons (Figures 5, 8, 9) ......................... 3
   Cephalothorax brown, abdomen dorsally sepia with white spots and white chevrons (Figures 6, 7) ................................. 7

3(2). Cephalic area dark brown, ventrolateral tibial apophysis with short lateral spike (Figures 12a, b) ............................ C. atriceps
Cavasteron and Minasteron

Cephalic area yellow, ventrolateral tibial apophysis without short lateral spike...... 4

4(3). DTA without internal tooth (P), (FA) of embolus base short (Figure 14a) C. laceratae
DTA with well developed internal tooth (P), FA well developed (Figures 21–23) ....... 5

5(4). Prong (FA) of embolus base short, rounded (Figure 21a), abdomen as in Figure 8 ......... C. agelenoides
Prong (FA) twice times as long as wide (Figures 22a, 23a) ................................. 6

6(5). Prong (FA) straight, fingershaped (Figure 22a), abdomen as in Figure 9 ....... C. index
Prong (FA) curved inwards (Figure 23a), abdomen as in Figure 5 ....... C. crassicalcar

7(2). Origin of embolus pointing retrrolaterad (Figure 20a); PE of DTA very large, reaching base of tibia C. exquisitum
Origin of embolus pointing backwards; PE of DTA not reaching base of tibia (Figures 13a, 15a–19a) ................................. 8

8(7). Internal tooth (P) of DTA strongly developed and sharp (Figures 17a, 19a). 9
Internal tooth (P) of DTA poorly developed, rounded and blunt (Figures 13a, 15a, 16a, 18a)........................................ 10

9(8). PE of DTA reaching tip of tibia, ventrolateral tibial apophysis with sharp downpointing prong (Figure 19b) ............................................... C. margaretae
PE of DTA much shorter not reaching tip of tibia, ventrolateral tibial apophysis with blunt downpointing prong, inner tooth (P) of DTA serrated and sharp (Figures 17a, b) .................................................. C. guttulatum

10(8). Anterior margin of DTA with shallow ridges (Figure 13b) ................. C. martini
Anterior margin of DTA smooth ........................................ 11

11(10). Embolus base with rounded prong (FA) (Figures 15a, 18a) .......................... 12
Embolus base without rounded prong (FA) (Figures 16a), cymbial claw poorly developed ....................................................... C. tenuicalcar

12(11). Ventrolateral tibial apophysis without downpointing prong; embolus base broad, frontal margin deeply indented (Figure 15a) ......................... C. triunguis
Ventrolateral tibial apophysis with recurved, blunt, downpointing prong, embolus base broadly curved, without frontal indentation (Figure 18a) ................................. C. mjoebergi

13(1). Cephalothorax yellow, abdomen dorsally pale with dark chevrons, copulatory ducts with three or four coils (Figures 5, 8, 9) ................................................................. 14
Cephalothorax brown, abdomen dorsally sepia with white spots or chevrons, central opening (CO) of epigyne small, broadly oval (Figure 29a), copulatory ducts (CD) with six coils (Figure 29b) ........................................... C. triunguis

14(13). Central opening (CO) of epigyne large, narrower towards back, copulatory ducts (CD) with three coils (Figure 28a, b) ............... C. agelenoides
Central opening (CO) of epigyne semicircular, widest at posterior margin, copulatory ducts (CD) with three coils (Figure 27a, b) ......................... C. crassicalcar

Cavasteron crassicalcar sp. nov.
Figures 1, 3, 5, 23, 27; Map 1

Material Examined

Holotype
δ, Australia, Western Australia, c. 3 km NNE. of Buningonia Spring (well), 31°26'S, 123°33'E; 18–25 November 1978, T. Houston et al. (WAM 90/219).

Paratypes
Australia: Western Australia: 5 δ, 39 km E. of Laverton, 28°28'S, 122°50'E, 2–3 November 1990, pitfall traps, E.R. Pianka (WAM, 2 δ in ZSM); 1 δ, same data except 26–27 October 1990, (WAM 99/2205); 3 δ, same data except 12–15 November 1989, E.R. Pianka (WAM 93/910–2); 3 δ, same data except 27–28 November 1990, E.R. Pianka (WAM 93/907–9, 1 δ in KBIN); 18 δ, 1 9, same data except 22–24 November 1990, E.R. Pianka (WAM 99/2206–2224); 1 δ, same data (WAM 99/2225); 2 δ, Goldfields Survey, Goonargie, GGR 3, 29°55'S, 121°08'E, October 1980, dune slack, W.F. Humphreys et al. (WAM 90/140–1); 1 δ, same data except GGR 4 (WAM 90/143); 1 δ, same data except GGR 8, depression in Atriplex (WAM 90/145); 2 δ, Buningonia Spring (Well), 5 km SE. of (BSR2), 31°26'S, 123°33'E, 18–25 November 1978, T.F. Houston et al. 225 (WAM 90/87–8); 2 δ, Red Sands, 28°12'S, 123°35'E, 5–7 November 1989, pitfall traps, E.R. Pianka (WAM 99/2226–7); 1 δ, Giles Weather Station, 25°02'S, 128°18'E, 13–15 January 1990, M.S. Harvey and T.F. Houston (WAM 93/897); 1 δ, Irrunyiju Rockhole, 26°07'S, 128°58'E, 19–21 January 1990, M.S. Harvey and T.F. Houston (WAM 93/899); 1 δ, Goldfields Survey, Goonargie, GGR 5, 29°55'S, 121°08'E, October 1980, mallee/Tridodia, W.F. Humphreys et al. (WAM 90/255); 1 δ,
Carnegie, NSE III, 28 March 1971, D. Williams (WAM 99/2228). South Australia: 1 \( \delta \), 5.5 km E. of Tallaringa Well, Tallaringa Conservation Park, 29°02'S, 133°21'E, 23–27 September 1993, ANZSES (SAMA N1994262); 1 \( \delta \), Middleback Station, railway line, 32°55'S, 137°15'E, December 1983, pitfall, B. Guerin (SAMA N1994420); 1 \( \delta \), same data (SAMA N1994421); 1 \( \delta \), same data (SAMA N1994422); 1 \( \delta \), 25 km SSW. of Mabel Creek, 29°10'S, 134°15'E, October 1984, stony tableland, C.R.A. Survey (SAMA N1992415); 1 \( \delta \), Iron Knob, 1959, at light, P. Aitken (SAMA N1992434); 1 \( \delta \), Gawler Ranges, Nonning, October 1985, N.P.W.S. Survey (SAMA N1992433); 1 \( \delta \), Johnson’s Dam, Granite Downs, 26°59'S, 133°35'E, December 1984, B. Guerin (SAMA N1994419).

Diagnosis

Males of this species are recognised by the large lobate flange on the palpal cymbium and the rounded internal prong on the retrolateral tip of the DTA (Figures 23a,b) which is conical in related species. The female is to be identified by the shape of the central membranous area on the epigyne (Figure 27a).

Description

Male (holotype)

Total length 5.86; carapace 2.91 long, 2.09 wide; tibia + patella 1.306.

Colour: Carapace and sternum yellow; chelicerae orange brown; legs pale yellow; abdomen (fig 5): dorsum sepia with intricate paler pattern; two spots followed by three chevrons and one contrasting white spot in front of spinnerets.

Tegument smooth.

Eyes: a: 0.20; b: 0.12; c: 0.15; d: 0.12; e: 0.04; f: 0.04; g: 0.10; h: 0.08; AL-AL: 0.30. MOQ: AW = 1.10 PW; AW = 0.96L.

Clypeus = 0.60 or 5.0 times diameter of ALE; chilum single, 0.10 high, 0.56 wide.

Leg spination

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Some strong ventral setae on Fel. Hinged hairs: T1 d1, TII d1.

Male palp (Figures 23a, b): tibial lateral concavity delimited by two apophyses; dorsal one bifid with sharp, slender mesal and truncated
lateral prong, both of similar length; ventrolateral one with swollen distal extremity connected with main part of segment by dorso-ventrally flattened ridge, seen as short spine in ventral view; prolateral extension of tibia with two macrosetae; cymbium with numerous dorsal spines, most distal one very large; proximal dorsal part depressed; flange flat, transparent, triangular with sharp tip; embolus long, slender, embolic base with curved frontal appendage with rounded tip; DTA large: retrolateral part with double extremity: external tip RE very finely serrated, internal tip P rounded; prolateral extension PE of DTA long.

Female
Total length 7.14; carapace 2.91 long, 1.99 wide; tibia+patella 1.2.35.
Colour: Carapace and sternum pale yellow, cephalic part darker yellow; cervical grooves with broad greyish band extended along fovea; chelicerae yellow; legs pale yellow, tarsi and metatarsi with slight orange tinge; abdomen pale with faint dorsal pattern of darker chevrons and bright white spot in front of spinnerets.
Tegument smooth.
Eyes: a: 0.17; b: 0.14; c: 0.17; d: 0.16; e: 0.04; f: 0.06; g: 0.06; h: 0.08; AL-AL: 0.28. MOQ: AW = 0.95 PW; AW = 0.83L.
Clypeus = 0.66 or 4.7 times diameter of ALE; chilum single, 0.16 high, 0.56 wide.
Leg spination

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Some strong ventral setae on FeL. Hinged hairs: TI d1, TII d1. Female palp swollen with numerous spines, a particularly large one on either side of finely toothed claw.
Epigyne (Figures 3c, d through 27a, b): a poorly sclerotized area with a central roughly oval membranous part; entrance ducts forming a double coil ending in poorly defined spermathecae.

Variation
Colour pattern sometimes much fainter than in
Figure 3 Cavasteron crassicalcar sp. nov. a, male palp, retrolateral view; b, ventral view; c, tarsal claw of leg IV; d, tarsal claw of leg I.
holotype; spination quite variable, even left and right sides sometimes with different number of spines: male carapace length and width vary between 1.18 and 0.98, 0.90 and 0.78.

Distribution
South Australia and Western Australia (Map 1).

Etymology
The species name is a noun in apposition (Latin crassus = thick, calcar = spur) referring to the large claw-shaped terminal spine on the palpal tarsus of male as well as female, which is typical for the genus of which this is the type species.

Cavasteron agelenoides sp. nov.
Figures 8, 21, 28; Map 2

Material Examined
Holotype

Paratypes
Australia: Queensland: 6 δ, 1 Ψ, same data as holotype (QM S3676, 2 δ in ZSM, 1 δ in KBIN); 5 δ, 1 Ψ, Simpson Desert, Ethabuka Station, 23°46'S, 138°28'E, 4–6 March 1999, sand dunes with Spinifex, R. Raven and B. Baehr (QM S50482).

Diagnosis
Males and females of this species are recognised by the peculiar spination, all tibiae having the same formula; males are further characterised by the large, rounded frontal appendage FA of the embolar base in the palp.

Description
Male (holotype)
Total length 5.81 carapace 2.40 long, 1.94 wide; tibia+patella I 1.78.
Colour: Cephalothorax, chelicerae, sternum and legs yellow; abdomen with faint darker V in front of fovea, running along eyes onto clypeus; abdomen entirely pale.
Tegument smooth.
Eyes: a: 0.18; b: 0.10; c: 0.16; d: 0.18; e: 0.04; f: 0.02; g: 0.08; h: 0.08; AL-AL: 0.28. MOQ : AW = 1.11 PW; AW = 0.95L.
Clypeus = 0.60 or 6.0 times diameter of ALE; chilum faint, not measured.

Leg spination
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No hinged hairs.

Epigyne (Figures 28a, b): a very poorly sclerotized plate, showing internal structure in transparency. Copulatory openings in the middle of the epigyne; copulatory ducts coiled, running forward, thence backward into fairly large, touching spermathecae near posterior margin.

Variation
Abdominal pattern variable: often very faint or even completely pale as in female paratype; leg spination slightly variable; male carapace length and width vary between 2.40 and 2.55, 1.94 and 2.14.

Distribution
Southwestern Queensland (Map 2).
Figure 4. Minasleron minutus minisculum sp. nov. a, male palp, retrolateral view; b, ventral view; c, tarsal claw of leg IV; d, tarsal claw of leg I.
Etymology
The species name is an adjective referring to the abdominal pattern reminding those found in many European Agelenidae.

**Cavasteron atriceps** sp. nov.
Figures 12a, b; Map 1

Material Examined

**Holotype**

* Australia, South Australia, Olympic Dam site, Roxby Downs, 3–5 November 1987, E. Matthews and C. Watts (SAMA N1992421).

**Paratype**


Diagnosis
Males of this species are recognised by the inferior retrolateral tibial apophysis provided with a short thorn and by the contrasting dark cephalic area on the yellow cephalothorax.

Description

**Male (holotype)**

Total length 6.88 carapace 3.06 long, 1.99 wide; tibia+patella I 2.75.


Eyes: a: 0.16; b: 0.11; c: 0.10; d: 0.11; e: 0.04; f: 0.00; g: 0.12; h: 0.10; AL-AL: 0.28. MOQ : AW = 1.12 PW; AW = 0.95L.

Clypeus = 0.46 or 4.2 times diameter of ALE; chilum single: 0.20 wide, 0.08 high, with some setae.

Leg spination

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</table>

thorn and by the contrasting dark cephalic area on the yellow cephalothorax.
Male palp (Figures 12a, b): tibial lateral concavity delimited by two apophyses: dorsal one with short, sharp, diverging prongs; tip ventrolateral apophysis with ventral swelling and short lateral spike; swollen tip; with translucent ridge linking this apophysis with body of tibia; prolateral extension with three (four on left side) macrosetae; cymbium with numerous spines, most distal one large, claw-shaped; flange a short translucent triangle with rounded tip; embolus long, slender, originating on posterior extremity of tegulum, basis pointing outward; embolar base without frontal excrescence; DTA large: retrolateral part with fairly short, sharp tip, but without internal tooth; prolateral extension of DTA.

Female
Unknown.

Variation
Abdominal colour pattern of paratype strikingly different: dorsum entirely sepia with three white spots: one on each side and one in the middle, one in front of spinnerets; further similar to holotype; spination stable; paratype carapace length and width: 1.99, 1.33.

Description
Male (holotype)
Total length 4.28; carapace 2.14 long, 1.43 wide; tibia+patella I 1.84.
Colour: Cephalothorax dark brown with darker radiating striae; chelicerae and sternum medium brown; coxae, trochanters, femora and patellae pale yellow, femora II, III and IV with dark stripes in distal part, femora I and patellae with dark stripes all over; tibiae, metatarsi and tarsi yellowish orange; abdomen (Figure 6): dorsum dark sepia with white pattern of two spots in front followed by two complex spots anastomosing in centre, two tiny adjacent spots and one larger spot in front of spinnerets; sides dark sepia with one large pale spot; venter pale sepia with darker quadrangular area with two small orange spots in front of epigynum; and dispersed small pale spots elsewhere.

Clypeus = 0.46 or 4.6 times diameter of ALE; chilum single, 1.16 wide, 0.08 high.

Leg spination
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One dorsal hinged hair on tibia I and II.

Male palp (Figures 20a, b): tibial lateral concavity delimited by two apophyses: dorsal one with two prongs: internal one short and sharp, external one equally short but blunt; ventrolateral one much longer than former with expanded extremity; ridge linking this apophysis with body of tibia not flattened, not visible from side; prolateral part of tibia with two macrosetae; cymbium with few dorsal spines, most distal one very large, claw-shaped; flange narrow, elongate, with rounded tip, hidden by DTA; embolus long, slender, originating on ventrolateral posterior extremity of tegulum, basis pointing outwards; embolar base BA with poorly developed prolateral ridge; DTA large: retrolateral part with long, sharp tip, and with rounded tooth; prolateral extension PE of DTA very long, reaching base of palpal tibia.

Female
Unknown.

Variation
Pattern of paratypes basically the same but less strongly contrasting; size and spination exactly as in holotype.

Material Examined
Holotype
♂, Australia, South Australia, 50 km S. of Innaminka, Strezlecki Creek, ca. 28°12'S, 140°25'E, 12 October 1987, at light, J. Forrest (SAMA N1992417).

Paratypes

Diagnosis
Males of this species are recognised by the long MOQ which is wider behind, the ventrolateral tibial apophysis which is much longer than the dorsolateral prongs, and the very long prolateral extension of the DTA.

Etymology
The species name is a noun in apposition (atriceps = black-headed) referring to the dark cephalic area of this species.

Cavasteron exquisitum sp. nov.
Figures 6, 20a, b; Map 1

Distribution
South Australia (Map 1).

Clypeus = 0.46 or 4.6 times diameter of ALE; chilum single, 1.16 wide, 0.08 high.

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One dorsal hinged hair on tibia I and II.

Male palp (Figures 20a, b): tibial lateral concavity delimited by two apophyses: dorsal one with two prongs: internal one short and sharp, external one equally short but blunt; ventrolateral one much longer than former with expanded extremity; ridge linking this apophysis with body of tibia not flattened, not visible from side; prolateral part of tibia with two macrosetae; cymbium with few dorsal spines, most distal one very large, claw-shaped; flange narrow, elongate, with rounded tip, hidden by DTA; embolus long, slender, originating on ventrolateral posterior extremity of tegulum, basis pointing outwards; embolar base BA with poorly developed prolateral ridge; DTA large: retrolateral part with long, sharp tip, and with rounded tooth; prolateral extension PE of DTA very long, reaching base of palpal tibia.

Female
Unknown.

Variation
Pattern of paratypes basically the same but less strongly contrasting; size and spination exactly as in holotype.
Figures 5-11 Abdomen dorsal view: 5, Cavasteron crassicalcar; 6, C. exquisitum; 7, C. temnicalcar; 8, C. agelenoides; 9, C. index; 10a, Minasteron perfoliatum; 10b, M. perfoliatum ventral view; 11a, Minasteron minusculum; 11b, M. minusculum ventral view. Scale = 0.5 mm.
Distribution
South Australia, and South West Queensland (Map 1).

Etymology
The species name is an adjective (Latin exquisitum = refined) referring to the strong marvellous colour pattern of this species.

Cavasteron guttulatum sp. nov.
Figures 17a, b; Map 2

Material Examined

Holotype
♂, Australia, South Australia, Coronation Bore, Mabel Creek Station, 29°11'S, 134°09'E, 31 October 1984, pitfalls, mulga sand plain, P. Greenslade (SAMA N1992416).

Paratypes
Australia: South Australia: 1 ♂, Muckera Rockhole, 30°02'S, 130°03'E, September 1984, B. Guerin (SAMA N1994423); 1 ♂, same data except pitfall (SAMA N1994424); 3 ♂, 25 km SSW. of Mabel Creek Station Homestead, 29°10'S, 134°15'E, October 1984, pitfall, P. Greenslade (SAMA N1992405-8, 1 ♂ in QM S50483).

Diagnosis
Males of this species are recognised by the pattern of the cephalothorax with paler patches in between the radiating striae, by the prolateral extension of the palpal tibia with three macrosetae and the short prolateral extension of the DTA.

Description
Male (holotype)
Total length 3.10; carapace 1.70 long, 1.40 wide; tibia+patella 11.60.

Colour: Cephalothorax medium brown with darker radiating striae, paler in cephalic area and with pale spots in between the striae; chelicerae orange, sternum yellowish orange; legs pale yellow, distal part of femora, patellae and tibiae with orange tinge; abdomen: dorsum dark sepia with complex pattern of two white spots in front followed by three chevrons and large white spot in front of spinnerets surrounded by black ring; sides pale with one dark stripe; venter pale.

Cephalothorax wide. Tegument smooth. Eyes: a; 0.12; b; 0.10; c; 0.10; d; 0.12; e; 0.03; f; 0.02; g; 0.07; h; 0.05; AL-AL; 0.26. MOQ: AW = 1.00 PW; AW = 0.81L.

Clypeus = 0.38 or 3.8 times diameter of ALE; chilium faint.

Leg spination

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Male palp (Figures 17a,b): tibial lateral concavity delimited by two apophyses: dorsal one very wide, at each extremity with a prong; internal one fairly long, curved, sharp, external one fairly short, blunt; ventrolateral one longer than former with expanded extremity; with flat, translucent ridge linking this apophyses with body of tibia; prolateral part of tibia with three macrosetae; cymbium with few dorsal spines, most distal one large, claw-shaped; flange lobate, triangular with rounded tip; embolus long, slender, originating on posterior extremity of tegulum, basis pointing prolaterally; embolar base with poorly developed frontal appendage FA; DTA large: retrolateral part with fairly short, sharp tip, and fairly sharp tooth; prolateral extension of DTA relatively short, not reaching palpal tibia.

Female
Unknown.

Variation
Colour pattern sometimes paler than in holotype; one paratype with black blotches at extremity of femora and tibiae; spination stable; male carapace length and width of paratypes are 1.66 and 1.70, 1.32 and 1.30.

Distribution
South Australia (Map 2).

Etymology
The species name is an adjective (Latin guttulatus = provided with drops) referring to the striking pattern of the male cephalothorax.

Cavasteron index sp. nov.
Figures 9, 22a, b; Map 2

Material Examined

Holotype
♂, Australia, Northern Territory, Powell Creek, 1933, C.B. (NMV K-3827).

Diagnosis
Males of this species are recognised by the fingershaped frontal appendage FA on the embolar base.

Description
Male (holotype)
Total length 5.25 carapace 2.44 long, 1.94 wide; tibia+patella 2.50.
Figures 12-14 12 *Cavasteron atriceps* sp. nov. a, right male palp, ventral view; b, retrolateral view. Scale = 0.25 mm. 13 *Cavasteron martini* sp. nov. a, right male palp, ventral view; b, retrolateral view. Scale = 0.25 mm. 14 *Cavasteron lacertae* sp. nov. a, right male palp, ventral view; b, retrolateral view. Scale = 0.25 mm.

Colour: Cephalothorax yellow with darker striae and faint dark V in front of fovea; clypeus with faint dark spot on anterior margin; chelicerae orange; sternum pale yellow; legs uniform pale yellow. Abdomen (Figure 9): dorsum sepia with intricate paler pattern: two spots followed by three chevrons and one contrasting white spot in front of spinnerets, sides and venter uniform white; yellow
tracheal spiracle with strongly sclerotised posterior margin, interrupts dark ring around spinnerets. Tegument smooth.

Eyes: a: 0.17; b: 0.12; c: 0.14; d: 0.18; e: 0.04; f: 0.05; g: 0.10; h: 0.08; AL-AL: 0.28. MOQ: AW = 1.00 PW; AW = 0.86L.

Clypeus = 0.58 or 4.8 times diameter of ALE; chilum single: 0.24 wide, 0.08 high.

Leg spination

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Male palp (Figures 22a, b): tibial lateral concavity delimited by two apophyses: dorsal one flat and deeply indented, thus creating two sharp prongs; ventrolateral apophysis strongly widened at extremity and truncated, inferior part sharp superior one rounded; ridge linking this apophysis with body of tibia with short, sharp projection; prolateral extension with three macrosetae; cymbium with numerous spines, most distal one large; flange a rounded lobe; embolus long, slender, originating on posterior extremity of tegulum, basis pointing backward; embolar base with fairly long finger-shaped, frontal appendage FA; DTA large: retrolateral part with fairly short, sharp tip and short rounded internal tooth; prolateral extension of DTA long, reaching mid of palpal tibia.

**Female**

Unknown.

**Variation**

Unknown.

**Distribution**

Northern Territory (Map 2).

**Etymology**

The species name is a noun in apposition referring to the finger-like projection on the embolar base.

*Cavasteron lacertae* sp. nov.

Figures 14a, b; Map 1

**Material Examined**

**Holotype**

♂, Australia, South Australia, north of Lake Eyre, ca. 28°30’S, 137°30’E, 11 December 1974, sandhills, in lizard traps, J.A. Herridge (SAMA N1992431).

**Paratypes**

Australia: Northern Territory: 1 ♂ Andado Station, 24°34’S, 135°16’E (SAMA N1994391).


**Other Material Examined**

Australia: South Australia: 2 ♂, Melbourne University Exploration of Lake Eyre, 19 July 1903 (NMV).

**Diagnosis**

Males of this species are recognised by the modified cymbium accommodating the proximal dorsolateral prong of the tibial apophysis and by the rounded, frontal appendage FA of the embolar base.

**Description**

Total length 5.86 carapace 2.45 long, 1.94 wide; tibia+patella 1.89.

Colour: Cephalothorax yellow with slightly orange tinge in cephalic area. Chelicerae yellowish orange; sternum yellow. Legs uniform pale yellow. Abdomen: dorsum pale with faint pattern of small isolated dark spots; sides and venter uniform cream; area in front of epigastric fold and tracheal spiracle pale yellow.

Cephalothorax fairly wide. Tegument smooth.

Eyes: a: 0.20; b: 0.12; c: 0.14; d: 0.16; e: 0.05; f: 0.03; g: 0.10; h: 0.05; AL-AL: 0.34. MOQ: AW = 1.10 PW; AW = 0.87L.

Clypeus = 0.60 or 5.0 times diameter of ALE; chilum single: 0.46 wide, 0.08 high.

Leg spination

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Male palp (Figures 14a, b): tibial lateral concavity delimited by two apophyses: dorsal one with diverging prongs: internal one laterally flattened but with tiny dorsal point, adjacent to cymbium which is modified to accommodate this prong; external one fairly long, standing out, blunt; ventrolateral apophysis with swollen tip; translucent ridge linking this apophysis with body of tibia well developed appearing as short point in lateral view; prolateral extension with two macrosetae; cymbium with proximal swelling; with numerous spines, most distal one large, claw-shaped; flange a short translucent triangle with fairly sharp tip; embolus long, slender, originating on posterior extremity of tegulum, basis pointing backward; embolar base with short, rounded internal tooth; prolateral extension of DTA large, reaching mid of palpal tibia.
Cavasteron and Minasteron

Figures 15-17  
Cavasteron triunguis sp. nov. a, right male palp, ventral view; b, retrolateral view. Scale = 0.25 mm. 16  
Cavasteron tenuicalcar sp. nov. a, right male palp, ventral view; b, retrolateral view. Scale = 0.25 mm. 17  
Cavasteron guttulatum sp. nov. a, right male palp, ventral view; b, retrolateral view. Scale = 0.25 mm.

Female
Unknown.

Variation
Colour pattern of paratype strikingly different:
carapace with faint dark “V” in front of fovea; 
dorsum of abdomen with clear dark pattern on pale background consisting of five chevrons, the first three anastomosing, surrounded by dark horseshoe-shaped line open towards the back; spination
variable, even left and right sides of holotype with some variation; male paratype carapace length and width 2.04, 1.53.

Distribution
South Australia, South Western Queensland and Northern Territory (Map 1).

Etymology
The species name is a noun, genitive (Latin lacerta = lizard) referring to the fact that the holotypes was caught in a lizard trap.

Cavasteron margaretae sp. nov.
Figures 19a, b; Map 2

Material Examined

Holotype
♂, Australia, Western Australia, Grasspatch, Fitz., 33°14'S, 124°43'E, 13 April 1979, on floor of toilet, A. Longbottom (WAM 90/153).

Paratype
Australia: Western Australia: 1 ♂, Buningonia Spring (Well), BSR2, 31°28'S, 123°36'E, August 1980, E. salubris woodland, W.F. Humphreys (WAM 90/93).

Diagnosis
Males of this species are recognised by deeply indented dorsolateral tibial apophysis with the internal prong long and sharp, the external one truncated; the tooth on the internal lamina of the DTA is ridge-shaped and not conical.

Description

Male (holotype)
Total length 3.87; carapace 2.09 long, 1.53 wide; tibia+patella l 2.04.
Colour: Carapace medium brown with darker radiating striae and dark V in front of fovea; clypeus with dark anterior margin; chelicerae orange brown; sternum pale brown suffused with dark on posterior lateral margins; legs: coxae, trochanters and distal part of femora pale yellow, distal part of femora dark with broad yellow stripes, patellae yellow suffused with black on sides; tibiae yellow suffused with black on sides of extremities, metatarsi and tarsi yellow; abdomen: dorsum dark sepia with intricate paler pattern: two reniform spots in front, followed by three chevrons, a pair of small spots and one large white spot in front of spinnerets; sides white, venter pale sepia.

Tegument smooth.

Eyes: a: 0.10; b: 0.10; c: 0.11; d: 0.12; e: 0.04; f: 0.02; g: 0.05; h: 0.10; AL-AL: 0.22. MOQ : AW = 0.86 PW; AW = 0.67L.

Leg spination

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<td>10 disp dw6</td>
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Hinged hairs: T1 dl. Til dl.

Male palp (Figures 19 a,b); tibial lateral concavity delimited by two apophyses: dorsal one deeply indented: internal prong long and sharp, external prong long and truncated; ventrolateral apophysis truncated with ventral edge swollen; flattened ridge connecting apophysis with body of tibia with short spine-like extension; prolateral extension of tibia with two macrosetae; cymbium with numerous dorsal spines, most distal one not as large as in most other members of genus; proximal dorsal part depressed, accomodating internal prong of dorsolateral tibial apophysis; flange semicircular, with rounded tip; embolus long, slender, originating on posterior extremity of tegulum, basis pointing backward; DTA large: retrolateral part with double extremity: external tip fairly short, internal tooth not conical but ridge-shaped; prolateral extension of DTA long, almost reaching base of tibia; prolateral ridge of tegulum well developed.

Female
Unknown.

Variation
Colour pattern of paratype more contrasted; carapace length and width of paratype 1.78 and 1.43.

Distribution
Western Australia (Map 2).

Etymology
The species name is a patronym in honour of the senior author’s mother.

Cavasteron martini sp. nov.
Figures 13a, b; Map 2

Material Examined

Holotype
♂, Australia: Western Australia, 2 km N. of Windjana Gorge, 17°20'S, 124°50'E, 22 November 1984, B. and M. Baehr (WAM 99/2229).

Diagnosis
Males of this species are recognised by strongly obliquely truncated ventrolateral tibial apophysis,
tapered at both extremities, and the ridged frontal appendage of the embolar base.

Description

**Male (holotype)**

Total length 4.18 carapace 2.29 long, 1.78 wide; tibia+patella 1.234.

Colour: Cephalothorax dark brown with faint darker radiating striae and dark V in front of fovea; chelicerae orange brown, sternum yellow suffused with dark brown; legs: coxae, trochanters and proximal part of femora pale yellow, distal part of femora dark brown with broad yellow stripes; remainder of legs yellow; abdomen entirely dark sepia except for a white dorsal pattern consisting of 2 pairs of small white spots in the middle, followed by three broken chevrons and a fairly large pale spot in front of the spinnerets.

Tegument smooth.

Eyes: a: 0.16; b: 0.12; c: 0.14; d: 0.14; e: 0.04; f: 0.02; g: 0.08; h: 0.12; AL-AL: 0.30. MOQ : AW = 1.05 PW; AW = 0.86L.

Clypeus = 0.60 or 5.0 times diameter of ALE; chilum single, 0.18 wide, 0.10 high.

**Leg spination**

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III & \text{pl3d3rll} & \text{pl1d1r1l} & \text{pl2d3r1v2-2-2} & 8\text{disp dw6} \\
IV & \text{pl2d3} & \text{pl1d1r1l} & \text{pl3d3r1v2-2-2} & 10\text{ disp dw6} \\
\end{array}
\]

Hinged hairs: one dorsal on tibiae I and II.

Male palp (Figures 13a, b): tibial lateral concavity delimited by two apophyses: dorsal one deeply indented, with two short prongs; ventrolateral apophysis broadened and obliquely truncated at extremity, both tips strongly tapered; ridge linking this apophysis with body of tibia with short spine-like, protrusion; prolateral extension with three macrosetae; cymbium with numerous spines, most distal one large, claw-shaped; lateral lobe semicircular, with rounded tip; embolus long, slender, originating on posterior extremity of tegulum, basis pointing prolaterad; embolar base ridged frontal appendage; DTA large: retrolateral part with fairly short tip, without internal tooth but with protruding ridge; prolateral extension of DTA fairly short, only reaching embolar base; prolateral part of tegulum ridged.

**Female**

Unknown.

**Variation**

Unknown.

**Distribution**

Known only from type locality (Map 2).

Etyymology

The species name is a patronym in honour of Martin Baehr, dedicated collector of Australian terrestrial invertebrates.

### Cavasteron mjoebergi sp. nov.

**Material Examined**

**Holotype**

♂, N.W. Australia, 12 October 1910, Y. Mjöberg (NHRS). Note: an immature with the holotype is probably not conspecific although superficially similar.

**Diagnosis**

Males of this species are recognised by the large AME, the simple abdominal pattern of three white spots on a dark background, the short prongs on the dorsolateral tibial apophysis and the well developed, short, rounded frontal appendage of the embolar base.

**Description**

**Male (holotype)**

Total length 4.33 carapace 2.39 long, 1.78 wide; tibia+patella 1.255.

Colour: Cephalothorax medium brown with paler striae and faint dark V in front of fovea; chelicerae medium brown; sternum yellow with orange tinge; legs uniform pale yellow. Abdomen: entirely dark sepia with three spots, one pair in middle, a single one in front of spinnerets.

Tegument smooth.

Eyes: a: 0.16; b: 0.10; c: 0.13; d: 0.14; e: 0.04; f: 0.02; g: 0.08; h: 0.10; AL-AL: 0.30. MOQ : AW = 1.00 PW; AW = 0.89L.

Clypeus = 0.58 or 5.8 times diameter of ALE; chilum single: 0.36 wide, 0.08 high.

**Leg spination**

\[
\begin{array}{cccc}
\text{Fe} & \text{Pa} & \text{T} & \text{Mt} \\
I & \text{pl1d3} & \text{pl1v2-2-2} & \text{v1-2-2dw3} \\
II & \text{pl2d3} & \text{pl1} & \text{pl2d1v2-2-2} & \text{pl1v1-2-2dw3} \\
III & \text{pl3d3r1} & \text{pl1d1r1l} & \text{pl3d3r1v2-2-2} & 10\text{disp dw6} \\
IV & \text{pl2d4r1l} & \text{pl1d1r1l} & \text{pl3d3r1v2-2-2} & 12\text{disp dw6} \\
\end{array}
\]

Male palp (Figures 18a, b): tibial lateral concavity delimited by two apophyses: dorsal one flat and indented, only internal side with short, sharp prong; ventrolateral apophysis obliquely truncated, both ends tapered and sharp; ridge linking this apophysis with body of tibia slightly indented thus forming short sharp tip; prolateral extension with three macrosetae; cymbium with numerous small spines, most distal one large; flange a triangle with rounded fairly sharp tip; embolus long, slender, originating on posterior extremity of tegulum, basis pointing outward; embolar base with broad
polarid ridge ending in fairly large rounded frontal appendage; DTA large: retrolateral part with fairly short, sharp tip, without internal tooth; prolateral extension of DTA long, reaching mid of palpal tibia.

Female
Unknown.

Variation
Unknown.
Cavasteron and Minasteron

**Distribution**
North-western Australia (Map 1).

**Eymology**
The species name is a patronym in honour of the Swedish spider collector E. Mjöberg.

*Cavasteron tenuicalcar* sp. nov.
Figures 7, 16a, b; Map 2

**Material Examined**

**Holotype**
♀, Australia, Western Australia, Mardie Station, 21°11’S, 115°59’E, July 1992, S. Jennings (WAM 93/1123).

**Diagnosis**
Males of this species are recognised by the poorly developed terminal cymbial spine on the cymbium and the frontal appendage on the embolar base without projection.

**Description**

*Male (holotype)*
Total length 3.72, carapace 1.93 long, 1.33 wide; tibia + patella 1.68.

Colour: Cephalothorax dark brown with darker striae and clear dark V in front of fovea; chelicerae medium brown; sternum medium brown, darker towards blackened margins; legs pale: femora II, III and IV with distal half dark brown, femora I yellow with distal 2/3 dark brown; tibiae with dark lateral stripes. Abdomen (Figure 7): entirely dark sepia with many small white spots a frontal pair, a central pair followed by a pair of procurved semicircular spots, a pair of tiny ones a single small one and a slightly larger one in front of spinnerets; sides dark sepia with large spot and oblique spot in front of spinnerets; venter uniform pale sepia; tracheal spiracle brown with numerous short spines.

Tegument smooth.

Eyes: a: 0.11; b: 0.09; c: 0.11; d: 0.10; e: 0.02; f: 0.02; g: 0.05; h: 0.09; AL-AL: 0.18. MOQ: AW = 0.89 PW; AW = 0.071L.

Clypeus = 0.30 or 3.3 times diameter of ALE; chilum single, triangular 0.10 high, 0.10 wide.

Leg spination

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<td>pl1d1r1l</td>
<td>pl2d3ril2-2-2</td>
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Tibiae I and II with one dorsal hinged hair.

Male palp (Figures 16a, b): tibial lateral concavity delimited by two apophyses: dorsal one flat and deeply indented; internal prong sharp, external blunt; ventrolateral apophysis truncated with thick extremity and a bunch of parallel setae; ridge linking this apophysis with body of tibia with rounded protrusion; prolateral extension of tibia with two macroseta; cymbium with few small spines, most distal one slightly larger; flange a triangle with rounded tip; embolus long, slender, originating on posterior extremity of tegulum, basis pointing backward; embolar base with broad frontal appendage but without projection; DTA large: retrolateral part with fairly long, sharp tip, without internal tooth but with slight bulge; prolateral extension of DTA long, reaching mid of palpal tibia.

**Female**
Unknown.

**Variation**
Unknown.

**Distribution**
Known only from type locality (Map 2).

**Etymology**
The species name is a noun in apposition and refers to the small terminal cymbial spur (L.: *tenuis* = slender, *calcar* = spur).

*Cavasteron triunguis* sp. nov.
Figures 15a, b, 29a-c; Map 1

**Material Examined**

**Holotype**

**Paratypes**
Australia: Queensland: 1 ♀, 1 ♂, collected with holotype; 1 ♂, 1 juvenile, CQ, Dunraven Station, NW. Hughenden, August 1985, A. Rozefelds (QM S3762); 5 ♂, 1 ♀, 4 subadult juveniles, SWQ, Birdsville, Lake Muncooniie, pitttrap in desert, 12–17 November 1976 (QM S3707, 1 ♀ in ZSM, 1 ♂ in KBIN).

**Diagnosis**
Males of this species are recognised by the peculiar abdominal pattern, the wide dorsolateral tibial apophysis with shallow protrusion and the cymbial modification accomodating the internal prong of the dorsolateral tibial apophysis. The female is to be identified by the oval shape of the central membranous copulatory opening of the epigyne.
Description

**Male (holotype)**

Total length 6.02; carapace 2.45 long, 1.73 wide; tibia+patella 1.24.

Colour: Carapace medium brown, with faint radiating striae and dark V in front of fovea; sternum and chelicera medium brown; legs pale yellow; extremity of femora with black sides, femora I entirely darkened; tibiae pale yellow, tibiae IV with faint lateral stripes; metatarsi and tarsi with orange tinge; abdomen: dorsum dark sepiá with intricate paler pattern: two large irregular spots in the middle, followed by single large spot in front of spinnerets; sides sepiá with small oblique spot in front and oblique stripe radiating from large dorsal spot; venter uniform pale sepiá; tracheal spiracle yellow with slightly darker posterior rim.

Tegment smooth.

Eyes: a: 0.14; b: 0.12; c: 0.11; d: 0.14; e: 0.03; f: 0.02; g: 0.11; h: 0.14; AL-AL: 0.22. MOQ : AW = 1.07 PW; AW = 0.84L.

Clypeus = 0.52 or 4.3 times diameter of ALE; chilium single, 0.10 high, 0.20 wide.

**Leg spination**

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</table>

Hinged hairs: TI d1, TI d1. Male palp (Figures 15a, b): tibial lateral concavity delimited by two apophyses: dorsal one flat and broad, shallowly indented: with two short prongs: internal one sharp, external one blunt, a shallow, finely ridged protrusion in between them; ventrolateral apophysis obliquely truncated with both extremities blunt: ridge linking this apophysis with main part of tibia translucent, with shallow, slightly pointed protrusion; prolateral extension of tibia with two macrosetae; cymbium with basal modification accommodating internal dorsolateral tibial prong: with numerous dorsal spines, most distal one very large; flange, transparent, triangular with rounded tip; embolus long, slender, embolar base with prolateral ridge ending in broadly rounded frontal appendage; DTA large; retrolateral part with fairly long sharp tip and lobate internal appendage; prolateral extension of DTA long, reaching prolateral tip of tibia.

**Female**

Total length 6.22; carapace 2.80 long, 1.94 wide; tibia+patella 1.24.

Colour: Carapace medium brown with broad pale margin in thoracic area, faint radiating striae; chelicerae and sternum medium brown; legs pale yellow, anterior femora, and all tarsi and metatarsi with slight orange tinge; abdomen: dorsum as in male but with extra pair of pale patches in front of large pair; sides and venter pale.

Tegment smooth.

Eyes: a: 0.16; b: 0.11; c: 0.14; d: 0.13; e: 0.04; f: 0.04; g: 0.06; h: 0.12; AL-AL: 0.20. MOQ : AW = 1.06 PW; AW = 0.86L.

Clypeus = 0.64 or 5.8 times diameter of ALE; chilium single, 0.10 high, 0.24 wide.

**Leg spination**

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Eyes: a: 0.16; b: 0.11; c: 0.14; d: 0.13; e: 0.04; f: 0.04; g: 0.06; h: 0.12; AL-AL: 0.20. MOQ : AW = 1.06 PW; AW = 0.86L.

Clypeus = 0.64 or 5.8 times diameter of ALE; chilium single, 0.10 high, 0.24 wide.

**Eyes:** a: 0.16; b: 0.11; c: 0.14; d: 0.13; e: 0.04; f: 0.04; g: 0.06; h: 0.12; AL-AL: 0.20. MOQ : AW = 1.06 PW; AW = 0.86L.

**Leg spination**

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**Distribution**

Southwest Queensland (Map 1).

**Etymology**

The species name is a noun in apposition referring to the female palpal tarsus which gives the impression to have three claws (Latin: *tri* = three, *unguis* = claw).

**Minasteron gen. nov.**

**Type Species**

*Minasteron minusculum* sp. nov.

**Diagnosis**

*Minasteron* shares some important diagnostic characters with *Cavasteron*: a large, terminal palpal claw in both sexes and several characters on the male palp: the dorsolateral bifid apophysis, the ventrolateral one which is connected by a dorsolaterally flattened ridge to the body of the tibia and the cymbium with a proximal, retrolateral lobe. *Minasteron* differs from *Cavasteron* by the higher profile of the carapace, the much smaller anterior eyes, the long MOQ, the greater number of spines on the anterior tibiae, the posterior tarsal claws which are almost straight and the looped palpal sperm duct.
Figure 21-23  

Cavasteron agelcoides sp. nov. a, right male palp, ventral view; b, retrolateral view. Scale = 0.25 mm. Abbreviations: BA base of embolus; E embolus; DTA dorsal tegular apophysis; F flange on cymbium; FA frontal appendage of base of embolus; P prong; PC palpal claw; PE prolateral extension of DTA; RE retrolateral extension of DTA; SP sperm duct. 

Cavasteron index sp. nov. a, right male palp, ventral view; b, retrolateral view. Scale = 0.25 mm. 

Cavasteron crassicalcar sp. nov. a, right male palp, ventral view; b, retrolateral view. Scale = 0.25 mm.

Description

Fairly similar to Cavasteron except in the following respects:

Small spiders (2.30–3.6) with smooth teguments. Carapace widest at level of coxae II, narrowed to 0.60 maximum width in females, to about 0.50 maximum width in males. Profile (Figure 2a) domed with highest point at PME.

Colour: carapace, chelicerae and sternum yellow; legs uniform yellow or with darker parts; abdomen
with strongly contrasted pattern.

Eyes (Figures 2b, c) in three rows (2-4-2). The first row is composed of the ALE, the second of the AME (in the middle) and PLE, the third of the PME. Second one strongly recurved as seen from above, so that it may seem that there are four rows of 2 eyes. Eyes of anterior row much smaller posterior eyes. MOQ almost twice as long as wide in front and twice as wide at the back. Clypeus straight or slightly convex, 5 to 7 times the diameter of an ALE; with few hairs. Chilum absent or single, then short and wide.

Legs: formula 4123. Spination: numerous on all legs. Paired tarsal claws with numerous (12-14) teeth on anterior leg pairs, with slightly fewer on those of legs III and IV. Claws (Figures 4c, d) of posterior pairs almost straight or poorly curved. Single claw on a well developed onychium.

Abdomen oval; with two muscle points; in the male with a narrow dorsal scutum in anterior half and with epiphragma. Tracheal spiracle almost straight and narrow with in front of it a sclerified area which may be bulging and then covered with short modified setae. Spinnerets as usual in the family; posterior pairs smaller in males than in females. Colulus represented by few hairs.

Basic structure of male palp (Figures 4a, b) and epigyne as in Cavasteron.

Etymology

Minasteron is a contraction of Asteron and minutus (Latin for "very small").

Key to species of Minasteron

1. Males

2. Females

1. Tegulum of male palp with spermduct strongly coiled, loop entirely in anterior part of tegulum, enclosing a relatively small area; indentation on lower prong of tibial apophysis delimiting tips of slightly different length; tip of RE with short, angular internal margin (Figures 26a, b) ....

2. Tegulum of male palp with spermduct less strongly coiled, loop occupying large part of tegulum, enclosing a relatively large area; indentation on lower prong of tibial apophysis delimiting tips of clearly different length; tip of RE with longer internal margin (Figures 24, 25) ....

3. Cephalothorax with strongly marked dark margin, clypeus with dark lateral areas often connected in the middle; abdomen with dark dorsal and ventral central areas and white dorsal spot in front of spinnerets (Figures 10a, b); tip of RE with fairly long but angular internal margin (Figure 25a) ....

M. perfoliatum

Cephalothorax without or poorly marked dark margin, clypeus without dark lateral areas; abdomen with pale pattern (Figure 11); tip of RE with long, smoothly rounded internal margin (Figure 24a) ....

M. minusculum

4(1). Cephalothorax with strongly marked dark margin, clypeus with dark lateral areas often connected .... in the middle; abdomen with dark dorsal and ventral central areas and white dorsal spot in front of spinnerets (Figures 10a, b); vulva with one spire ....

M. perfoliatum

Cephalothorax without or poorly marked dark margin, clypeus without dark lateral areas; abdomen with pale pattern (Figure 11); vulva with at least two spires ....

M. minusculum

Minasteron minusculum sp. nov.

Material Examined

Holotype

Male, Australia, Western Australia, Woodstock Station, WS10, 21°40′S, 119°02′E, 10–17 February 1989, wet pit traps, Dell, How and Waldock (WAM 99/2230).

Paratypes

Australia: Western Australia: 1♂, collected with holotype; 1♂, Woodstock Station, site WS6, 21°36′S, 119°01′E, 10–17 February 1989, wet pit traps, J. Dell, R. How and J. Waldock (WAM 99/2231); 3♂, Woodstock Station, site WS5, 21°36′S, 118°59′E, 3–9 May 1988, wet pits, J. Waldock (WAM 93/1006-8); 4♂, Barrow Island, John Wayne Country, 20°45′S, 115°22′E, 4–30 November 1993, sandy site, wet pitfall traps, M.S. Harvey, J.M. Waldock (WAM 95/248-51); 2♂, Woodstock Station, site WS4, 21°36′S, 118°58′E, 23–30 September 1988, wet pit traps, J. Dell et al. (WAM 99/2232-3); 5♂, Woodstock Station, site WS1, 21°37′S, 118°57′E, 10–17 February 1989, wet pits, Waldock, How and Dell (WAM 99/2234-8); 2♂, same data except site WS9, 21°37′S, 119°01′E (WAM 99/2239-40); 22♂, 2♀, Woodstock Station, site WS3, 21°37′S, 118°58′E, 10–17 February 1989, wet pits, hard Spinifex sandplain, Waldock, How and Dell (WAM 99/2241-64); 1♂, Woodstock Station, site WS1, 21°37′S, 118°57′E, 10–17 February 1989, Acacia coriacea thicket, J. Dell, R. How, J. Waldock (WAM 99/2265); 8♂, Woodstock Station, site WS4, 21°36′S, 118°58′E, 3–9 May 1988, wet pits.
Figures 24–26  

24 Minasteron minusculum sp. nov. a, right male palp, ventral view; b, retrolateral view. Scale = 0.25 mm.

25 Minasteron perfoliatum sp. nov. a, right male palp, ventral view; b, retrolateral view. Scale = 0.25 mm.

26 Minasteron tangens sp. nov. a, right male palp, ventral view; b, retrolateral view. Scale = 0.25 mm.

J. Dell and J. Waldock (WAM 93/977-84), 2 ♂ in KBIN, 2 ♂ in ZSM); 1 ♂ 1 ♀, Woodstock Station, site SW5, 21°36'S, 118°59'E, 23 March 1988, wet pitfalls, W.F. Humphreys (WAM 93/937-4); 14 ♂, Woodstock Station, site WS3, 21°36'S, 118°57'E, 23–30 September 1988, wet pit traps, J. Dell et al. (WAM 99/2266-79); 3 ♂, same data except 23–30 March 1988, W.F. Humphreys (WAM 93/931-32); 1 ♂, Woodstock Station, site WS2, 21°36'S, 118°57'E, 3–9 May 1988, fenceline, J. Dell (WAM 93/96); 21 ♂, 2 ♀, Barrow Island, 1 km of Warehouse, 20°43'S, 115°25'E, 4 November–3 December 1993, wet pitfall traps, M.S. Harvey and J.M. Waldock (WAM 95/290-314); 22 ♂, 3 ♀,

Diagnosis

Males of this species are recognized by the carapace with only a faint dark margin and the pale abdomen; the ventral prong in the palpial apophysis has more differently-sized tips than M. tangens; the question-mark-shaped loop on the tegulum encloses a larger area than in M. tangens; the main difference with M. perfoliatum is in the shape of the tip of the DTA which has a smoothly rounded internal curve (Figure 24a).

Description

Male (holotype)

Total length 3.06; carapace 1.43 long, 1.07 wide; tibia+patella I 1.38.

Colour: Sternum, chelicerae and cephalothorax yellow, with a slight orange tinge in cephalic area; legs pale yellow; abdomen (Figure 11): entirely pale grey with clear white patch in front of dorsum.

Tegument smooth.

Eyes: a: 0.05; b: 0.05; c: 0.10; d: 0.11; e: 0.02; f: 0.05; g: 0.06; h: 0.06; AL:AL: 0.10. MOQ : AW = 0.50 PW; AW = 0.46L.

Clypeus = 0.34 or 6.8 times diameter of ALE; chilum absent.

Leg spination

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\end{array}
\]

Male palp (Figures 24a, b): tibial lateral concavity delimited by two apophyses: dorsal one ventrolaterally flattened with two short, blunt prongs of similar length; ventrolateral one with tapered and indented distal extremity, forming two tips of different length, and ventral swelling connected with main part of segment by dorso-ventrally flattened ridge with tiny sharp protrusion, seen as very short spine in ventral view; prolateral part of tibia with two macrosetae; cymbium with numerous dorsal spines, most distal one very large, claw-shaped; flange small, flat, transparent, lobate with rounded tip; embolus long, slender, originating on prolateral posterior extremity of tegulum; embolar base with very short sharp tip; area enclosed by sperm duct large; DTA large: RE bent, and with ridge-shaped P; prolateral extension of DTA short, about half as long as bulbus.

B. Baehr, R. Jocqué
Female (from Woodstock, 10–17 February 1989)

Total length 3.52; carapace 1.54 long, 1.12 wide; tibia+patella I 1.22.

Colour: Carapace and sternum pale yellow with dark margin and some dark mottling on lateral part of clypeus.

Further in all respects similar to male.

Epigyne (Figures 30a, b): a hardly sclerotized oval plate with posterior darker rim adjacent to the well defined central copulatory opening; transparent, showing internal structure of long copulatory ducts, running forwards thence backwards in a coil, and poorly delimited spermathecae.

Variation

Colour pattern slightly variable: the legs may be uniform or provided with poorly delimited dark blotches; Spination quite variable, even left and right sides sometimes with different number of spines: male carapace length and width vary between 1.33 and 1.68, 0.87 and 1.27; in females between 1.48–1.94 and 1.02–1.33.

Distribution

Western Australia (Map 3).

Etymology

The species name is an adjective (Latin minusculus = very small) referring to the size of this species.

Minasteron perfoliatum sp. nov.

Figures 10a, b, 25a, b, 31a, b; Map 3

Material Examined

Holotype

♂, Australia, South Australia, Sand plain, 28 km SW. of Mabel Creek Homestead, 29°10'S, 134°20'E, October 1984, P. Greenslade (SAMA N1994350).

Paratypes

Australia: South Australia: 8 ♂, 2 ♀, collected with holotype (SAMA N1994351-60); 11 ♂, Mabel Creek Station, 11 November 1984, pitfalls, dune, P. Greenslade (SAMA N1992437-47, 2 ♂ in KBIN, 2 ♂

**Diagnosis**

The species is very similar to *C. minusculum* but is recognised by the dark margin of the carapace, the chyleus with two dark lateral area interconnected in the middle, the dark spot in front on the chelicerae, the peculiar dark abdominal pattern (Figure 10a, b). Males are further recognized by the question-mark-shaped area enclosed by the sperm duct in the tegulum which is larger than in *M. minusculum* and the RE more slender than in the other species. The main difference with *M. minusculum* is in the shape of the tip of the DTA which has an angular internal margin (Figure 25a). The female is identified by details of the epigyne in which the frontal margin of the oval copulatory opening is ill-defined.

**Description**

**Male (holotype)**

Total length 2.34; carapace 1.27 long, 1.07 wide; tibia+patella I 1.22.

Colour: Carapace yellowish brown with dark margin dark V in front of fovea and dark U-shaped mottling on chyleus; chelicerae yellowish orange, sternum pale yellow; legs yellow with distal end of femora and extremities of tibiae brown; abdomen (Figure 10a) strongly contrasted: dorsum dark seipia with large white spot in front of spinnerets and large pale spots on sides meeting in front; venter white with slightly darker central band (Figure 10b).

Tegument smooth.

Eyes: a: 0.06; b: 0.06; c: 0.11; d: 0.12; e: 0.03; f: 0.03; g: 0.06; h: 0.07; AL-AL: 0.10. MOQ: AW = 0.53 PW; AW = 0.50L.

Chyleus = 0.38 or 6.3 times diameter of ALE; chilum single, 0.06 high, 0.28 wide.

**Leg spination**

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<td>IV</td>
<td>pl2d4r1</td>
<td>pl1d1r1r1</td>
</tr>
</tbody>
</table>

Hinged hairs: TI d2, TI d2.

All claws with numerous teeth. Tarsal claws of posterior legs poorly curved.

Male palp (Figures 25a, b): Tibial lateral concavity delimited by two apophyses: dorsal one ventrolaterally flattened with shallow indentation leaving two short, blunt prongs of similar length; ventrolateral one with indented distal extremity, forming two tips of different length, ventral swelling connected with main part of segment by dorso-ventrally flattened ridge, with short sharp protrusion, seen as very short spine in ventral view; prolateral part of tibia with two macrosetae; cymbium with numerous dorsal spines, most distal one very large, claw-shaped; flange small, flat, transparent, lobate with rounded tip; area enclosed by sperm duct large; embols long, slender, originating on prolateral posterior extremity of tegulum; embolar base with very short, sharp tip; DTA large: RE narrow, with angular inner margin, and with ridge-shaped P; prolateral extension of DTA short, about half as long as bulbus.

**Female**

Total length 3.57; carapace 1.53 long, 1.12 wide; tibia+patella I 1.22.

Colour: Carapace yellow with almost black margin interrupted before chyleus; with brown spot around fovea and one spot on either side in front of it; chyleus with large brown band under PLE; chelicerae and sternum yellow; legs yellow with distal end of femora and extremities of tibiae brown; abdomen: dorsum pale with complex pattern of white guanine leaving a central slightly darker area and two rows of three dark spots in posterior half; sides densely mottled with white; venter cream.

Tegument smooth. Chyleus with several large setae.

Eyes: a: 0.08; b: 0.08; c: 0.13; d: 0.14; e: 0.04; f: 0.04; g: 0.10; h: 0.08; AL-AL: 0.16. MOQ: AW = 0.60 PW; AW = 0.53L.

Chyleus = 0.42 mm or 5.2 times diameter of ALE; chilum single, 0.07 high, 0.26 wide.

**Leg spination**

<table>
<thead>
<tr>
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<th>T</th>
<th>Mt</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
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<td>pl2r1v2-2-2</td>
</tr>
<tr>
<td>II</td>
<td>pl1d3</td>
<td>pl2r1v1-2-2</td>
</tr>
<tr>
<td>III</td>
<td>pl1d3r1</td>
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<tr>
<td>IV</td>
<td>pl2d4r1</td>
<td>pl1d1r1r1</td>
</tr>
</tbody>
</table>

B. Baehr, R. Jocqué
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Figures 27–29  Cavasteron crassicalcar sp. nov.  a, epigyne;  b, epigyne, cleared, ventral view.  Scale = 0.25 mm.
28  Cavasteron agelemonoides sp. nov.  a, epigyne;  b, epigyne, cleared, ventral view.  Scale = 0.25 mm.
29  Cavasteron triunguis sp. nov.  a, epigyne;  b, epigyne, cleared, ventral view;  c, female palp.  Scale = 0.25 mm; CD copulatory duct; CO copulatory opening; S spermatheca.
Variation

The abdominal colour pattern of the male is very variable depending on the extent of the white lateral patches: the anterior narrow black area may considerably vary in width just as the central black band on the venter; the dark folium very often has two ill-defined, white, central spots; the dark spots in front of the fovea may be absent in paler specimens; spination variable, left and right sides sometimes with different number of spines; male carapace length and width vary between 1.27-1.48 and 1.02-1.22.

Material Examined

Holotype

$\delta$, Australia, Queensland: Ethabuka Station, 23°46'S, 138°28'E, 4-6 March 1999, pitfalls, some Spinifex, R. Raven and B. Baehr (QM S50485).

Paratypes

Australia: Queensland: 1 $\delta$, collected with holotype (QM S50486); 4 $\delta$, same data (QM...
Cavasteron and Minasteron


Diagnosis
This species is closely related to M. perfoliatum and M. minusculum. The main difference is that the question-mark-shaped sperm-duct in the tegulum encloses an area which is smaller than in both the other species; the tips of the indented lower prong of the tibial apophysis are less different in length (Figures 26 a, b).

Description
Male (holotype)
Total length 2.74 carapace 1.28 long, 1.04 wide; tibia+patella I 1.20.
Colour: Cephalothorax uniform yellowish orange with thin dark margin and two medium brown spots on clypeus above chelicerae; chelicerae yellow; sternum and legs uniform pale yellow. Abdomen: white with pale yellow longitudinal central mark.
Tegument smooth.
Eyes: a: 0.06; b: 0.06; c: 0.10; d: 0.10; e: 0.03; f: 0.03; g: 0.06; h: 0.06; AL-AL: 0.22. MOQ: AW = 1.56 PW; AW = 2.00L.
Clypeus = 0.32 or 4.8 times diameter of ALE.
Leg spination
Tibiae I and II with one dorsal hinged hair.
Male palp (Figures 26a, b): tibial lateral concavity delimited by two apophyses: dorsal one ventrolaterally flattened with shallow indentation, the most proximal prong distinctly longer than the ectal one; ventrolateral one with elongate triangular indented extremity, leaving two tips of slightly different length, and ventral swelling connected with main part of segment by dorso-ventrally flattened ridge, with short sharp protrusion, seen as very short spine in ventral view; prolateral part of tibia with one macroseta; cymbium with very few dorsal spines, most distal one very large, claw-shaped; flange small, flat, lobate with rounded tip; area enclosed by sperm duct small; embolus long, slender, originating on prolateral posterior extremity of tegulum; embolar base with concave prolateral side and curved retrolateral side, distal tip rounded, slightly protruding; DTA large: RE with short, angulater internal curve, and with ridge-shaped P; prolateral extension of DTA short, about half as long as bulbus.

Female
Unknown.

Variation
Unknown.

Distribution
Known from the area where Queensland, Northern Territory and South Australia meet (Map 3).

Etymology
The species name is an adjective and refers to the close relationship with the other species in the genus.

DISCUSSION
The present taxa, endemic to Australia, occur mostly in desert and semi-desert areas. They apparently dig in sand which is usually covered by a crust held together by lichens. The large palpal claws might be seen as a tool to pierce that relatively hard crust. Both genera are obviously night active.
The genera and their species treated in this paper only represent a small part of the Asterol-complex as defined by Baehr and Jocqué (1996). In that paper these taxa form the crassicaulkar-clade, named after the type species of Cavasteron in the cladogram presented there. Although this is a relatively small group, it is obvious that here again, as for instance in the other zodariid genera Storena (Joeque and Baehr, 1992) and Diores (Joeque, 1990), there is wide range in the length of the embolus and, correlated with this, the length of the female copulatory ducts. This is clear when one compares the relative length of these structures in C. martini and C. exquisitum.

Supplementary reasons to assume that an increase in length of the intromittent organ has taken place for reasons explained in earlier zodariid revisions and the analysis thereof in Jocqué (1998). Further study of the phenomenon in this huge species-complex might throw more light on the reasons for this evolution: do these structures represent a lock and key system, or are they the result of female choice or mate check?

ACKNOWLEDGEMENTS
We are indebted to the curators of the collections mentioned under "Materials and Methods" above. We thank A. Reygel for the preparation of Figures 1, 2 and 5–11 and especially Mark Harvey for the preparation of the distribution maps.
REFERENCES

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Fish associations within the different inland habitats of lower south-western Australia

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Abstract – In order to determine whether certain fish species or groups of species are associated with the different habitat types occurring in the inland waterbodies of south-western Australia, 239 sites sampled between Margaret River and Broke Inlet were assigned to appropriate Ramsar wetland categories and their fish assemblages then subjected to classification. Each of the sample sites fell into one of the following categories, pools (ephemeral or permanent), riverine (fresh or salt affected), reservoirs, lacustrine (fresh or saline) or estuarine. One-way analysis using ANOSIM in the PRIMER package suggested that the fish communities of the ephemeral pools were significantly different to those of the rivers and lakes. Thus, the ephemeral pools were characterised by the presence of the endemic and restricted species, *Lepidogalaxias salamandroides* and/or *Galaxiella nigrostriata*, whereas the permanent rivers and lakes of the region were characterised by a fauna dominated by the other small endemic freshwater teleosts, i.e. *Galaxias occidentalis*, *Galaxiella munda*, *Bostockia porosa*, *Edelia vittata* and *Namatherina balstoni* and in many cases the lamprey *Geotria australis*. ANOSIM also showed that there were significant differences between the fish faunas in each of the freshwater habitats in the study region when compared to the estuarine and salt affected waterbodies of the region. The species most commonly encountered in the estuarine and salt affected sites included the estuarine affiliated *Leptatherina wallacei* and *Pseudogobius olorum*, the endemic *G. occidentalis* and also the introduced *Gambusia holbrooki*.

INTRODUCTION

In 1971, several countries met in Ramsar, Iran to identify and discuss wetlands of international importance. Since that time, interest in wetlands has been increasing such that there are currently 106 countries which are signatories to what is now known as the Ramsar Convention (Phillips, 1993; iucn.org/themes/ramsar/about_infopack_4e.htm 4/9/1998). One of the outcomes of this convention was the development of numerous wetland habitat categories, which, in order to suit Australian conditions, have subsequently been modified by the Australian Nature Conservation Agency (Phillips, 1993). These broadscale types of habitat include, to name a few, freshwater and estuarine reaches of rivers, freshwater and saline lakes, permanent and ephemeral pools and also artificial waterbodies of various kinds. Although many of the waterbodies located in the south-western corner of Australia can be easily placed into one of the above modified Ramsar categories, others are either combinations of Ramsar’s categories or fall outside any of their definitions. For example, the ephemeral pools of the peat flat region occur, by definition, on organic/humic soils and are thus a combination of the Ramsar categories B10 (seasonal/intermittent freshwater ponds and marshes on inorganic soils) and B15 (peatlands; forest, shrubs or open bogs), while salt affected waterbodies are not included in the classification (Phillips, 1993). The absence of a category for saline affected waterbodies is probably due to their relative paucity in the populated areas of the northern hemisphere (e.g. Europe and North America) (Williams, 1988; Phillips, 1993). The unnatural salinisation of waterbodies, however, is not confined to the south-west of Australia, but is becoming increasingly common in semi-arid regions of the world such as south-eastern Australia and southern and northern Africa (see for example Williams, 1988; Morelli and Drewien, 1993; Shaw and Newton, 1993).

While it is known that some of the freshwater fish species found in south-western Australia have very restricted distributions and occur in very specific habitat types, e.g. the salamanderfish *Lepidogalaxias salamandroides* is essentially restricted to some ephemeral pools of the peat flats (Christensen, 1982; Pusey and Edward, 1990; Morgan et al., 1998), other species, such as the western minnow *Galaxias occidentalis*, nightfish *Bostockia porosa* and western...
pygmy perch *Edelia vittata*, are far more widespread and occur in a variety of habitat types (Christensen, 1982; Allen, 1989; Pusey and Edward, 1990; Morgan et al., 1998).

The first aim of this paper was to define, for lower south-western Australia, the main waterbody types using Ramsar's definitions, and where necessary provide new/modified habitat definitions. The second aim, using the data presented in Table 2 of Morgan et al. (1998), was to determine if certain fish species or groups of species are associated with specific habitat types.

**MATERIALS AND METHODS**

**Selection of data to be included in analyses**

This study utilizes data collected in the area between Margaret River and Broke Inlet (see Table 2 in Morgan et al., 1998). The association of species and/or suites of species within particular habitats was determined by estimating the similarity of the fish faunas based on the presence or absence of each species in each site. It should be noted that presence/absence data were preferred over abundance data for this study as all sites were not sampled in the same season and that the relative abundances change markedly between seasons in the south-west of Australia. For example, during winter, when the region receives the majority of its rainfall, water levels are extremely high and fish densities are consequently greatly reduced. In contrast, during summer, when there is little or no rain and evaporation is high, water levels fall dramatically and fish densities increase substantially. Thus, while the relative abundance of species at each site could not be confidently estimated, intense sampling at each site using several techniques (e.g. gill, seine, larval and scoop nets, electrofishing etc, see Morgan et al., 1998 for precise details) provided a high degree of conviction that all of the species of fish present at each site were likely to have been captured.

Sites representing each of the following habitat types in lower south-western Australia as defined by Ramsar, i.e. permanent rivers and streams, permanent lakes, permanent freshwater pools, estuarine or intertidal waters and water storage areas, e.g. dams, and those habitats not defined by Ramsar, i.e. ephemeral pools and salt affected waterbodies, were included in the analyses.

It should be noted that those statistical packages which are currently available for generating similarity matrices and for the subsequent testing of these matrices, utilise agglomerative techniques to provide visual representations of any associations, i.e. classification dendograms and ordination plots. These packages can normally only 'handle' a set maximum small to moderate number of samples, e.g. TAXAN2 - 100 samples, SPSS-X - small to moderate number of samples (not defined), PRIMER - 124 samples. As the current study sampled more than 400 sites (= 400 samples) (see Table 2 in Morgan et al., 1998), a rationalisation and reduction of sites for inclusion in these analyses was necessary. Thus, the 239 sites sampled in the waterbodies between Margaret River and Broke Inlet (see Table 2 in Morgan et al., 1998) were selected for this part of the study as this region contains the majority of fish species that inhabit inland waters in south-western Australia, and this region also incorporates all of those different habitats defined above. Furthermore, this region also contains the largest river system in south-western Australia, as well as both cleared areas and some of the least disturbed areas of south-western Australia. Of the 239 different sites sampled during this study in the above watersheds, fish were not captured in 55 and these sites were thus omitted from further analyses. Furthermore, adjacent and seasonally connected sites were amalgamated if they were of the same habitat type and contained a similar suite of species. This reduced the total number of sites for analysis to 123, which is a suitable number for analyses to be performed using PRIMER.

**Classification of sample sites, ANOSIM and SIMPER**

On the basis of a species presence or absence, the distribution of the different fish species amongst the 123 sites was used to construct a similarity matrix employing the Bray-Curtis similarity coefficient in PRIMER (Clarke and Warwick, 1994). To illustrate the extent of similarity in the faunal composition of these sites, the matrix was then subjected to classification using PRIMER (Clarke and Warwick, 1994). In order to test the proposition that the different broad habitat types outlined above will contain different fish faunas, the 123 sites sampled were *a priori* allocated to one of these habitats and the significance of any faunal differences between these broad groups was tested by one-way analysis using ANOSIM in the PRIMER package (Clarke and Warwick, 1994).

Since more than half, i.e. 63, of the sample sites were within group V in the initial classification (see Figure 1), and as the other groups were likely to have strongly influenced the expression of variation within this group of the classification, the sites in group V were separately subjected to classification. The species that distinguish the two large resultant groupings from each other within this classification (see Figure 2), were then determined using SIMPER (similarity percentages) (Clarke and Warwick, 1994).
RESULTS

Classification of the different fish faunas at the different sampling sites produced five major groups (Figure 1). The first group of sites (I) was dominated by species with marine affinities, i.e. the western hardyhead *Leptatherina wallacei*, Swan River goby *Pseudogobius olorum* and big headed goby *Afurcagobius suppositus*. All of these sites were either estuarine or salt affected waterbodies. Group II comprised those sites that were of an ephemeral nature and contained predominantly *L. salamandroides* and/or the black-stripe minnow *Galaxiella nigrostriata*. However, other endemic freshwater teleosts, such as *G. occidentalis*, *B. porosa*...
Further classification of the sites in Group V of Figure 1. The site number (see Table 2 in Morgan et al. (1998)) and the prevailing habitat type, as well as those species present at each site, are given. N.B. For Geotria australis — ammocoetes (larval) are represented by an italicised 9, adults by a bolded 9 and when both are present a standard (i.e. not bolded or italicised) 9 is given.

### Habitat type

1. Ephemeral pools
2. Permanent pools
3. Freshwater rivers and streams
4. Freshwater lakes
5. Estuaries
6. Saline rivers
7. Dams

### Species

1. Tandanus bostocki
2. Lepidogalaxias salamandroides
3. Galaxias occidentalis
4. Galaxiella nigrostriata
5. Galaxiella munda
6. Bostockia porosa
7. Edelia vittata
8. Nanoutherina balstoni
9. Geotria australis
10. Leptatherina wallacei
11. Pseudogobius olorum
12. Afuragobius supposilus
13. Oncorhynchus mykiss or Salmo trutta
14. Gambusia holbrooki
15. Perea/luviatilis
and *E. vittata*, were also commonly found in these environments, which they utilise as both spawning and nursery grounds. The small number of sites that comprised group III were either headwater streams or seasonal water bodies and were characterised by the presence of the mud minnow *Galaxiella munda* and either one or two other endemic species (Figure 1). The sites in group (IV) in Figure 1 were from saline rivers, and were characterised by the presence of the introduced Gambusia holbrooki, but also included *G. occidentalis*, *L. wallacei*, *P. olorum* and to a lesser extent *B. porosa* and *Oncorhynchus mykiss/Salmo trutta*. Group V, which contained the majority of sites sampled, i.e. 63, comprised those sites with a relatively 'natural' assemblage of fishes, with the dominant species being those that are endemic to the south-west of Australia and also the lamprey *Geotria australis*. Furthermore, those species which have been introduced into the region, such as the mosquitofish *G. holbrooki*, redfin or Eurasian perch *Perca fluviatilis* and the trout species *O. mykiss/S. trutta* were also recorded in some of these sites. The habitats within this group included both ephemeral and permanent pools, streams, lakes and dams (Figure 1).

When the samples for Group V were classified separately, three distinct groups were apparent (Figure 2). The first group (I) in this dendogram contained two outliers, with the first site containing only *E. vittata*, while the other contained *E. vittata* and *P. olorum*. The classification then, with respect to the remaining sites, produced two main groups (Figure 2). The smaller group (II), which contained exclusively freshwater riverine or dammed sites, was shown by SIMPER to be characterised by the presence of *G. australis*. Within this group, the other species that were found in most sites included *E. vittata*, *B. porosa* and *G. occidentalis*. The larger group (III) contained these three latter species at most sites, and were of a wide range of habitat types, e.g. ephemeral and permanent pools, freshwater rivers and streams, freshwater lakes, saline rivers and dams.

The distinct differences between the species composition in the saline waters (e.g. estuarine and Blackwood River) and the fresh waters in south-western Australia are further highlighted when the fish faunas of the different habitat types (i.e. ephemeral pools, permanent pools, fresh rivers, lakes, estuarine, salt affected rivers and dams) are subjected to one-way analysis using ANOSIM. Thus, ANOSIM showed that there were indeed significant faunal differences (p<0.05) between each of the freshwater habitats in the study region when compared to each of the saline habitat types. ANOSIM also showed that there were significant differences (p<0.05) between the fish fauna of ephemeral pools of the region and those of the rivers and lakes, this being a reflection of the absence of *L. salamandroides* and *G. nigrostriata* from the vast majority of the latter habitats (Table 1).

The tabulation of the number of sites at which each species occurred for each of the habitat types further illustrates the associations described above (Table 1). Thus, *L. salamandroides* and *G. nigrostriata* were essentially restricted to the pools of the region, being found in 25 and 24 of the 32 ephemeral pools sampled, and in two and five of the 10 permanent pools sampled, respectively. In contrast, *G. occidentalis*, *B. porosa* and *E. vittata* were most frequently found in permanent freshwater habitats, i.e. lakes, rivers and pools. Thus, these three species

### Table 1

The number of sites within each broad habitat type, between Margaret River and Broke Inlet, that each of the inland fish species of south-western Australia were captured. The total number of sites sampled in each habitat type is also given.

<table>
<thead>
<tr>
<th>Species</th>
<th>Ephemeral pools (32)</th>
<th>Permanent pools (10)</th>
<th>Riverine (32)</th>
<th>Lakes (16)</th>
<th>Estuarine (7)</th>
<th>Salt affected (17)</th>
<th>Dams (8)</th>
<th>Salt lakes (1)</th>
<th>TOTAL (123)</th>
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<td>Namatherina balstoni</td>
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<td>12</td>
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<td></td>
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<tr>
<td>Gambusia holbrooki</td>
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<td><em>Perca fluviatilis</em></td>
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</table>
were captured in 49, 45 and 56 of the 66 permanent freshwater habitats sampled, respectively (Table 1). The remaining two small endemic species, *G. munda* and *N. balstoni*, were much rarer, being found only in ephemeral pools (three each), permanent pools (four and five, respectively) and in riverine sites (five and four, respectively). *Namathertia balstoni* was also captured in four lakes. The freshwater catfish or cobbler *Tandanus bostocki* was very rarely captured during this study.

*Leptatherina wallacei* was not captured in the freshwater rivers of the region. It was, however, found in one fresh and one salt lake, four estuarine sites and nine salt affected river sites. Similarly, *P. olorum* was most often found in estuarine (seven) and salt affected sites (six), but also in freshwater rivers (two) and lakes (two) and in one salt lake. Both of the latter species were very occasionally captured in ephemeral pools (Table 1). The other species that is commonly associated with estuaries, i.e. *A. suppositus* (see Morgan et al., 1998), was found in two estuarine sites, one freshwater lake, one salt affected river and two freshwater riverine sites. The lamprey *G. australis* was only captured in riverine sites (15) and in dams (two), as were the introduced trout (seven and five sites, respectively) and *P. fluviatilis* (five and three sites, respectively). The remaining introduced species, *G. holbrooki*, was captured on more occasions, being found in 32 sites in both fresh (10) and salt affected (12) rivers, lakes (five) and dams (five) (Table 1).

**DISCUSSION**

While two of the endemic freshwater species of south-western Australia, i.e. *L. salamandroides* and *G. nigrostriata*, are essentially restricted to ephemeral pools, the five remaining small endemic freshwater teleosts are found in a wider variety of habitat types such as streams, lakes and ephemeral and permanent pools. Of these latter species, *N. balstoni* and *G. munda* were found in fewer sites than the other small endemic species, namely *G. occidentalis*, *B. porosa* and *E. vittata* (see Table 1; Morgan et al., 1998). It should be noted that, like *L. salamandroides* and *G. nigrostriata*, *N. balstoni* and *G. munda* are restricted in their distribution and are most common in the waterbodies of the peat flats.

Since *G. occidentalis*, *G. holbrooki*, *L. wallacei*, *P. olorum* and *A. suppositus* were all found in a wide range of salinities, they must be at least moderately euryhaline. The other teleosts caught during this study were almost always captured in fresh waters and it can therefore be assumed that these species are either stenohaline or show strong preferences for fresh water. The results presented in this paper demonstrate that the salinisation of water bodies in south-western Australia is likely to cause a decline in the number of endemic freshwater species in such systems. In contrast, the introduced *G. holbrooki* and also those species commonly associated with estuaries, i.e. *L. wallacei* and *P. olorum*, are likely to either become more prevalent in waters which have higher than ‘normal’ salinities or are not going to be affected by such conditions. The salinisation of many freshwater habitats, through land clearing within the immediate catchment, is increasing in south-western Australia and is causing the extinction or decline in populations of other aquatic fauna and also flora, and consequently, is having major effects on stream ecology (Hart et al., 1991; Pen, 1997). Thus, while certain macrophytes, microalgae, fringe vegetation, invertebrate species and waterbirds may increase in abundance in such saline systems, others may decline (Hart et al., 1991; Williams, 1995). Within the Blackwood River (the largest salt affected river in Western Australia with an average annual increase in dissolved salts of ca 15 mg/L (Schofield and Ruprecht, 1989; Pen, 1997)), for example, Williams et al., (1991) found little or no longitudinality with regard to faunal composition of this system, despite the salinity gradient along its length. Although this is likely to be a consequence of an increase in halotolerant species, it presumably also indicates that there has been an elimination of less tolerant species that once characterised a more diverse system (Trayler et al., 1996). It could therefore be argued that the increasing salinity in the Blackwood River is resulting in a loss of populations of endemic freshwater teleosts and a concomitant increase in halotolerant species such as *L. wallacei*, *P. olorum* and *G. holbrooki*.

It is worth noting that when the introduced species *G. holbrooki* and *P. fluviatilis* were present in artificial environments, e.g. dams, the native species were rarely captured. In contrast, in riverine sites, native and introduced fish species were often found together, however, during the periods when water levels were greatly reduced and sections of rivers became a series of small pools, native fish were usually absent in those pools that harboured *P. fluviatilis* and/or the two trout species. When the results of this study are considered in conjunction with the studies of Hambleton et al. (1996), Morgan and Gill (1996) and Gill et al. (1998), it becomes evident that the small endemic freshwater teleosts of south-western Australia are vulnerable to the continuing loss or alteration of habitat and to the introduction of agonistic or piscivorous species such as *G. holbrooki* and *P. fluviatilis*.

The fact that adult and larval (ammocoetes) lampreys were only captured above four of the eight dams sampled may reflect the fact that large dam walls can act as a major barrier to the upstream migration of lampreys and that dams may also modify flow regimes and thereby cause adverse changes to the sediment composition of ammocoete beds.
Freshwater fish assemblages of south-western Australia

While this paper has provided data on the broad scale habitat associations of the fishes of lower south-western Australia, it does not provide information on their specific habitat requirements, preferences and tolerances, e.g. suitable spawning substrate, flow regimes, preference for complex habitats, and pH and salinity tolerances. Future studies should therefore be aimed at the provision of such information, which will aid in both the formulation of management plans for the conservation of this unique fauna and also the identification of prospective habitats for their re-introduction.

ACKNOWLEDGEMENTS

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A new stygobiont melitid amphipod from the Nullarbor Plain

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Abstract - A new genus and species of melitid amphipod, Nurina poulteri, from the Nullarbor Plain, Western Australia, is described. The new taxon, from two caves in the Roe Plain region, is compared with melitids from elsewhere in Australia, and possible origins relevant to the recent geological history of the region are discussed.

INTRODUCTION

Stygobiont amphipods are being recorded in increasing numbers from widespread regions of Australia. The number of described troglobite or troglophilic species is now near 50 (Bradbury and Williams, 1997a, b). The actual number of known species is, however, much greater as many are in the process of description or held in collections pending taxonomic treatment. The majority is associated with groundwaters in carbonate rocks which have been karstified. The Nullarbor Plain, approximately 200,000 km², located in central southern Australia around 30–32°S latitude between longitudes 124° and 132°E, is a region of Tertiary limestones, which arose from the sea in the Middle Miocene (15 MYA).

After final emergence from the sea the Nullarbor limestones underwent karstification, including the development of caves which intersect the regional groundwater table, although few of these underground lakes appear to contain aquatic macroinvertebrates. Richards (1971) recorded no aquatic fauna from a comprehensive survey of many caves, suggesting that low effective precipitation, general absence of permanent surface streams, and phreatic origin of the caves with no evidence of marine inundation, precluded colonisation either by marine or freshwater species. This is probably largely true, except in one region, the Roe Plains, an eroded area of coastal lowland in the central Nullarbor extending a distance of almost 300 km from Twilight Cove (~32°20'S, 126°E) to Wilson Bluff (~31°40'S, 129°E) and up to 40 km wide. This area of uplifted sea bed is low lying, compared with most of the Nullarbor, not exceeding a maximum altitude of 30 m above sea level at its northernmost margin, and adjacent the Southern Ocean in the Great Australian Bight along the southern edge. Although Richards (1971) found no evidence of marine invasion in Nullarbor caves, there are indications of sea-levels as high as 30 m above the present level. Among Roe Plains caves, therefore, marine intrusive species, or relict marine species might well be expected, as has been found in other regions of similar geological history, such as North West Cape (Humphreys and Adams, 1991; Knott, 1983; Barnard and Williams, 1995; Bradbury and Williams, 1996, 1997b), the Ashburton River and lower Fortescue River areas in northern Western Australia (Bradbury, unpublished), and in the Flinders Ranges of South Australia (Barnard and Williams, 1995).

Knott (1983, 1985) reported on a 1982 collection from waters of Nurina Cave (one of the Roe Plains caves). He noted a number of amphipods thought to be of the genus Melita Leach. These specimens have not, however, been formally described. Several genera and species attributed to the Melitidae have already been recorded from other regions of Australia that have been subject to marine inundation (Bradbury, 1999); all are stygobionts. One of us (S.E.) accessed Nurina Cave (#N46) as well as the unnamed adjacent cave designated cave N1327, in December 1998, and was able to collect amphipod specimens from both sites. Three species of three amphipod families were represented in the collections. The most abundant, and the dominant species, which is described here, and the only taxon taken from Nurina Cave, is almost certainly that collected in 1982 and reported by Knott (1983); the other two taxa will be treated elsewhere, in conjunction with related collections.

METHODS OF DISSECTION AND DESCRIPTION


The notation M, with an appended number, indicates the position of an object as a fraction of the distance from the base to the apex of an
appendage; S large spine; s, small spine. Abbreviations used in the figures are as follows: A, antenna; Abd, abdomen; acc, accessory; C, coxa; d, dorsal; dact, dactylus; E, epimeron; fl, flake; flag, flagellum; g, gill; G, gnathopod; Hd, head; i,– inner; juv, juvenile; L, left; lac, lacinia mobilis; LL, lower lip; MD, mandible; med, medial; mol, molar; MP, maxilliped; MX, maxilla; o, outer; O, oostegite; opp, opposite; p, palp; P, pereopod; PC, prebuccal complex; pl, plate; Pp, pleopod; R, right; sp, spine; sq, square view; sr, setae removed (sometimes marked by sockets); st, sternal gill; T, telson; U, uropod; UL, upper lip; UR, urosome; 1, 2, 3 ..7, first, second, third ..seventh article, segment, somite or uropod; UL, upper lip; UR, urosome; 1, 2, 3 ..7, first, second, third ..seventh article, segment, somite or epimeron (as appropriate).

Mandibular palp setae are described using the notation of Karaman (1969) and Barnard and Barnard (1983).

SYSTEMATICS

Family Melitidae Bousfield, 1973

Nurina gen. nov.

Type Species

Nurina poulteri sp. nov.

Diagnosis

Pleonite six dorsolaterally naked, pleonite 5 with robust dorsolateral seta; rostrum obsolete; lateral cephalic lobes strongly projecting, large, plate like, with distinct ventral notch formed by the blunt extension of the anterodorsal margin. Eyes absent. First antenna longer than the second, ratio of peduncular articles 1:1.3:0.5. Accessory flagellum four articulate, the fourth article tiny. Upper lip asymmetrical, ovate and apically ptilose. Mandible: palp three articulate, article one short, naked; third article with CDE setae; accessory blades numerous, with interraker plumose setae and brushy basal setae onto the molar. Lower lip: bearing broad inner lobes. Maxillae: moderately setose medially, ovato-triangular, facially setose (pubescent), with medial and apical plumose setae; outer plate with nine denticulate robust setae, palps asymmetric the left with thin apical and subapical setae, the right with apical broad spines fused to the article as well as apical and subapical setae. Inner plate of second maxilla without plumose medial setae, but some naked paired medial setae extending to the apex, some facial. Both plates of second maxilla with naked apical and subapical setae of medium to moderate length and both with few marginal setules (pubescence). Maxilliped: inner plate long, extending to M0.7 of outer plate, with a medial submarginal disto-facial row of plumose setae extending more facial apically, blunt, naked tooth like robust setae subterminally and an apical row of plumose setae; outer plate large, with long, curved, robust apical plumose setae continuous with a distal row of submarginal to apical, short to long naked tooth setae, and medial to sub marginal to facial paired rows of long naked setae; medial margin straight, without marginal robust setae, the distomedial corner quadrangle; palp article two short, article three elongate, with no lateral setae; article three moderately to densely setose medially, with a row of long setae at the base of the dactyl distolaterally and facially; apex produced slightly, bearing marginal setules, dactyl unguiform, multispinous, without facial setules (not pubescent), bearing a long naked nail with basal setae. Coxae: one to four normal, longer than broad, lacking posterior robust setae; coxae one to three subquadrate, not apically expanded; coxa four moderately excavate posteriorly; coxa five shorter than four; female coxa six anterior lobe ventrally extended, coxa seven small, unlobed anteriorly. Gnathopods: diverse, gnathopod one much smaller than gnathopod two, dactyl of gnathopod one without recumbent inner tooth spine, both dactyls with distinct nail. First gnathopod small, merus lacking hyaline lobe, without rastellate seta, carpus longer than propodus, not lobate, palm of propodus transverse, short, deeply notched in males, distal row of long robust setae borne on palmar submargin each with a small subapical trigger; gnathopod two enlarged, 1.5–2.x gnathopod one, carpus short, triangular and lobate, dactyl enlarged and ovate, palm strongly oblique, setose, defining corner absent, but indicated by limit of robust setae; dactyl shorter than extent of robust setae. Pereopods: three and four shorter than pereopods five to seven, posterior setae on article six of pereopods three and four evenly spaced, weak; pereopods five to seven moderately long, six longest, the others subequal in length, the basis (article 2) moderately expanded, ovato-rectangular, posteriorly extended and slightly lobate; dactyls of pereopods lacking accessory spinules other than the usual single posterior and anterior setules. Coxae two to six each bearing a single flask shaped gill, that of coxa six sub equal in size to the gill of coxa five. Without sternal gills. Oostegites: present on coxae two to five of mature females; narrow, marginally poorly setose. Epimera: posterodorsal corner of epimera one to three acuminate, but without spine or setae, posterior margins straight to slightly convex, with moderate numbers of setae; epimera two and three with facial robust setae near the ventral margin. Pleopods: peduncles with few setae, rami extending equally, basomedial setae of inner rami bident; retinaculae two per pleopod, plus two accessory retinaculae. Uropods: apico-lateral corner of peduncles of uropods one and two with one and two robust setae; lateral- and medial- dorsal margins of peduncle of first uropod spinose, of
A new stygobiont amphipod

second naked; first uropod with basofacial robust seta; rami of uropod one subequal, the lateral ramus of uropod two shorter than the medial; rami of both uropods with two robust seta rows; third uropod strongly extended, peduncle of moderate length, outer ramus large of one article only, inner ramus short and scale-like; lateral and medial setae of outer ramus dense; peduncle with apical, medial and distal robust setae. Urosome: ventrodextral robust seta on urosomite one at base of uropod one absent. Telson: short and scale-like; lateral and medial setae of outer ramus large of one article only, inner ramus setose medially; the first antenna is chelate, and the mandibular palp three articulate. However, Nurina differs from Melita in that: the eyes are lost; the second peduncular article of the first antenna is relatively longer, the third shorter; the primary flagellum of the first antenna is relatively much shorter – 2x vs 5x the length of the peduncle; the accessory flagellum is of four articles, rather than 2+; the third article of the mandibular palp bears C as well as D and E setae; the inner lobes of the lower lip are broad, but thin and poorly developed rather than well developed and fleshy; the inner plate of the first maxilliped is triangular rather than ‘falcatotriangular’ being straight not curved, and the outer plate bears nine robust denticulate setae as opposed to 7+; the dactyl of the maxillipedal palp is barely curved, not unguiform.

Nurina differs from Psammoniphargus Karaman in that the third uropod is distinctly parviramous and the anterior coxae are significantly longer than posterior coxae; from Galapciellus J. L. Barnard and Anchialella J. L. Barnard in that the peduncle of the third uropod is not elongate, the second gnathopod strong and the carpus not elongate; from Psammoniphargus in that the lower lip bears inner lobes and the mandibular palp is not reduced to a single article; from Nainaloe Karaman and Barnard and Rotomelites J. L. Barnard in that the telson is not rectangular, but tapering and without excavate apices; from Melitoides Gurjanova in that the third uropod exceeds the length of the first in the undissected specimen; from Victoriopisa Karaman and Barnard and Eriopisa Stebbing in that anterior coxae are significantly longer than posterior and that the third uropod is without a second article on the outer ramus; from Materiopa Barnard and Karaman and Paraniphargus Tattersall in that maxillae bear medial setae; from Dulichiella Stout in that the male second gnathopods are not asymmetrical, the body is smooth, without transdorsal serrations, and the inner plate of the first maxilla bears many setae and is not sickle like; from Tegano Karaman and Barnard in that the mandibular palp is not reduced to two articles.

Species Composition
Nurina contains only N. poulteri sp. nov.

Etymology
Named for the type location, Nurina Cave, Western Australia. The gender is feminine.

Nurina poulteri sp. nov.
Figures 1-5

Type Locality
Underground water, Nurina Cave, Roe Plains, Western Australia, Australia, 127°01'E, 32°0'S.

Material Examined
Holotype
δ', 'a' 9 mm (WAM C 24436), Nurina Cave N46, Roe Plains, Western Australia, Australia, 127°01'E, 32°0'S, 31 December 1998, S. Eberhard.

Allotype
♀, 'b' 7.5 mm (WAM C 24437), same data as holotype.

Paratypes
1 δ, 8.9 mm (WAM C 24438) and 15 other specimens, same data as holotype.

Other Material
Australia: Western Australia: 2 ♀, cave N1327, Roe Plains, 127°01'E, 31°57'S, 10 April, 1997, N. Poulter and D. Hall (WAM BES 4648, BES 4651); 8 ♀, same data except 31 December 1998, S. Eberhard (WAM).

Relationships
The family Melitidae is characterised (Barnard and Barnard, 1983) by: the lower lips usually bearing inner lobes weak to fleshy; maxillae fully to not setose medially; the first gnathopod and also the female second gnathopod “melitid” in form; with a distinct palm; the male second gnathopod enlarged, the dactyls simple; pleonites and peraeopods 3-4 are ordinary, 5-7 basis variably setose medially; the third uropod is parviramous; the telson is not elongate, inner lobes are present on the lower lip, the telson tapers distally, uropod three extends beyond uropod one in the whole specimen, anterior coxae are significantly longer than posterior coxae, the maxillae are weakly setose medially, the second gnathopod not bilaterally diverse, nor chelate, and the mandibular palp three articulate. However, Nurina differs from Melita in that the peduncle of the third uropod is not elongate, inner lobes are present on the lower lip, the telson tapers distally, uropod three extends beyond uropod one in the whole specimen, anterior coxae are significantly longer than posterior coxae, the maxillae are weakly setose medially, the second gnathopod not bilaterally diverse, nor chelate, and the mandibular palp three articulate. However, Nurina differs from Melita in that: the eyes are lost; the second peduncular article of the first antenna is relatively longer, the third shorter; the primary flagellum of the first antenna is relatively much shorter – 2x vs 5x the length of the peduncle; the accessory flagellum is of four articles, rather than 2+; the third article of the mandibular palp bears C as well as D and E setae; the inner lobes of the lower lip are broad, but thin and poorly developed rather than well developed and fleshy; the inner plate of the first maxilliped is triangular rather than ‘falcatotriangular’ being straight not curved, and the outer plate bears nine robust denticulate setae as opposed to 7+; the dactyl of the maxillipedal palp is barely curved, not unguiform.

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Allotype
♀, 'b' 7.5 mm (WAM C 24437), same data as holotype.

Paratypes
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Australia: Western Australia: 2 ♀, cave N1327, Roe Plains, 127°01'E, 31°57'S, 10 April, 1997, N. Poulter and D. Hall (WAM BES 4648, BES 4651); 8 ♀, same data except 31 December 1998, S. Eberhard (WAM).
Figure 1  *Nurina poulteri* male 8.9 mm: whole, holotype, male ‘a’: right gnathopod 1 and palm, left gnathopod 2, right pereopod 3.
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Diagnosis
As for the genus.

Description of holotype (male ‘a’)

Body (Figure 1): Length 9 mm. Urosome with few, scattered weak setules, urosomite five with one distolateral robust seta. Head: rostrum obsolescent, eyes absent. First antenna (Figure 1): Length 0.6 x body, 1.4 x second antenna; flagellum longer than peduncle, of twenty articles, the ultimate article tiny; peduncle article one 0.7 x the second which is longest, the third shortest, ratio of articles 1: 1.3: 0.5, article one with few setae, bearing a ventrodorsal group of simple and penicillate setae and one robust seta; sparse short and long setae present on articles two and three; calceoli and aesthetascos absent; accessory flagellum four articulate, the ultimate article tiny, extending to M0.3 of the fifth article of the primary flagellum; primary flagellum sparsely setulate, articles 3–4 short. Second antenna (Figure 1): length 0.4 x body, peduncle much longer than flagellum, articles four and five equally long, sparsely setulate, other articles with few setae, length ratio of articles 1:3.3:3:1; flagellum short, eight articulate, moderately setose, lacking calceoli. Upper lip: asymmetrical, offset to the right, ovate, apically pilose. Lower lip (Figure 2): bilobed, the inner lobes broad, weak, extending to M0.7 of the outer lobes; outer lobes with strong denticulate distal setae, medial and distomedia! pilia. Left mandible (Figure 2): palp three articulate, ratio of articles 1.3:5:3, the first article short and naked, the second longer, linear with article one with few medial and no lateral setae; article three sublinear, lacking A or B setae, with 1C, 3D, 4E setae; incisor bearing five teeth, lacinia mobilis four, accessory setal row of eight rakers and four interrakers; molar with distal plumose seta and peripheral posterior pubescence. Right mandible (Figure 2): palp similar, article two bearing few setae, article three with 1C, 3D, 4E setae, mandible with five teeth, lacinia mobilis bifid and strongly denticulate. First maxilla (Figure 2): left and right sides asymmetrical; inner plate ovatotriangular bearing eight left and seven right plumose distimomial and apical setae covered in short setules (pubescence); outer plate bearing nine denticulate terminal robust setae on both sides, facially setulate (pubescent); left palp, second article with a sub apical row of eight slender setae and six apical slender to strong naked setae; right palp article two with a sub apical row of seven naked and one distally plumose setae, two mediodistal naked setae and three broad tooth spines fused to the apex. Second maxilla (Figure 2): apicomedial margin of both plates setulate (pubescent), terminating in long naked, curved setae in apical and sub apical rows; medial setae of inner plate not plumose although some terminally lastellate. Maxilliped (Figure 2): peduncle bearing few setae; inner plate subrectangular, facially and distolaterally setulate (pubescent); the outer plate bearing a medial submarginal row of fourteen naked tooth setae continuous with a medial subapical row of four tooth setae, all increasing in length distally forming a submedial pallisade row of teeth, distomedial to apicofacial paired rows of naked setae, an apicolateral to apical row of four long plumose setae, apicofacially and apicolaterally pubescent; the inner plate with a medio- to apico¬facial row of eleven plumose setae, seven apicolateral plumose setae and three sub apical strong naked tooth spines; medial margin straight, naked, the apicomedial corner subquadrature; palp article three with a medial to distolateral row of long setae, and a row of long setae basal to the dactyl, the apex marginally setulate with a group of slender setae facial at the hinge of the dactyl, the dactyl itself bearing three accessory posterior setules and two setules basal to the nail. First gnathopod (Figure 1): small; coxal plate subrectangular, apically rounded with an apico¬marginal row of eight long, slender setae and five anterovelvelal short slender setae; carpus subtriangular, short about 0.5x propodus, not lobate, bearing post-transverse rows of strong rastellate and a few elongate simple slender setae; propodus trapezoidal, apically expanded, longer than wide with few anterior, posterior and facial setal rows, seven clusters of elongate facial seta at the dactyl base; palmar corner subquadrate, the palm short, marginally finely denticulate, strongly notched, with a sub palmar row of seven strong setae between the corner and notch, the palmar angle transverse to slightly oblique; the dactyl short, with three medial setae and a long slender seta basal to the nail, reaching almost to the palmar corner. Second gnathopod (Figure 1): much larger then the first; coxal plate subrectangular, broadly rounded apically with four short anterovelvelal and seven longer apical setae; merus postdistally extended, lobate, bearing transverse posterior rows of long setae; propodus much enlarged, three times the first gnathopod, ovate, longer than wide – 1.5x – with seven transverse dorsal (anterior) rows and six ventral (posterior) rows of setae; palm strongly oblique, rounded without a clearly defined palmar corner, the palm delineated by a marginal row of robust trigger setae and long slender simple setae; the dactyl short of the palmar corner bearing a row of small hooked setae sub marginal to the proximal edge, a small recumbent inner tooth spine and single seta basal to the nail. Pereopods (Figures 1, 3): pereopods three and four equal in length, longer than the gnathopods; coxa three subrectangular, apically rounded, broader than long, with only a
Figure 2 *Nurina poulteri* holotype, male 'a': mouthparts (all illustrations except where indicated); allotype, female 'b': apex of right first maxilla palp.
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Figure 3  *Niirina poulteri* holotype, male ‘a’: pereopods 4–7.
few marginal setae ventrally; coxa four ovatoretangular, moderately excavate posteriorly, with small marginal ventral setae; coxae five and six bilobed; coxa five with a single slender seta ventral on the anterior lobe and small ventral and postventral setules; coxa six with two very small posterior setules; coxa seven lacking an anterior lobe, bearing one small posterior setule. Pereopods three and four second article bearing long, straight, distally curved posterior setae, articles three and four with few short to medium length setae, articles five and six with mixed slender and robust setae. Pereopods five to seven; basis moderately expanded, with small posteroventral lobes, short to medium length anterior robust setae and short, weak posterior setae; merus to propodus well armed with long robust and slender setae, extremely long posteriorly on the carpus of each, dactyls without accessory setae except the normal single posterior and outer penicillate setules. Gills (Figure 5): coxae two to six bearing flask shaped gills, decreasing in size posteriorly, although gill six not significantly smaller than gill five. Pleopods (Figure 4): peduncles each bearing two retinaculae and two accessory retinaculae distomedially, and few short setae, some plumose; rami subequal in length, basal articles each with several setae, the lateral and medial robust setae, the postventral corner acuminate but not spinous, the posterior margin slightly convex, almost straight, with six small setules; epimeron two with two anteroventral submarginal robust setae, the postventral corner acuminate, not spinous, the posterior margin slightly sinuous with five small setae; epimeron three with three marginal naked setae, otherwise without dorsofacial setation.

Description of allotype (female 'b')

Similar to the holotype, except in the following: Body: Length 7.5 mm. Mandibles: palps three articulate, ratio of article lengths R - 20:54:45, L - 20:58:45, setae of article three of both 1C, 2D, 4E. Maxillae: inner plate of first maxilla bearing L 8, R8 plumose medial and apicominal setae; palps asymmetric, left palp second article terminating in long strong setae, to the holotype, the right palp terminating in strong setae and broad fused tooth spines, differing from the holotype in number of denticulations (Figure 2). First gnathopod (Figure 5): first gnathopod small, smaller than gnathopod two, similar to the male holotype except that the palm lacks a notch. Second gnathopod (Figure 5): much larger than gnathopod one; propodus large, ovatarectangular; palm without a clearly defined corner, indicated by the extent of robust trigger bearing setae; dactyl slightly shorter than the palm, bearing two facial setules a small recumbent inner tooth spine at the base of the nail and a row of submarginal hooked setae; coxae (Figure 5) two to five each bearing, in addition to a flask shaped gill, narrow, moderately setose oostegite, the anterior lobe of coxa six extended ventrally into an elongate curved plate. Uropods. First uropod: peduncle bearing a robust ventrofacial seta, a dorsolateral row of three robust setae and two apicolateral robust setae, and a dorsomedial row of two robust setae and one apicominal robust setae; rami subequal in length, the inner ramus being slightly longer, the outer ramus bearing two lateral and two medial robust setae, the inner ramus with one lateral and three medial robust setae, and each with five apical robust setae. Second uropod: smaller than the first, 0.6x the length; the peduncle length equal to the inner ramus, slightly longer than the outer (1.1x), peduncle bearing single apicolateral and apicominal robust setae; outer ramus with two dorsolateral and one dorsomedial robust setae and five apical robust setae, the inner ramus with two dorsolateral, two dorsomedial and five apical robust setae. Third uropod: strongly extended, length 0.8x uropod one; peduncle short, less than 0.5x the length of the outer ramus, with five apicolateral robust setae and one apicominal robust seta basal to the inner ramus; inner ramus small, scale like, 0.4x peduncle length, bearing a single distal robust seta; outer ramus elongate, one articulate, linear, sub rectangular with a width to length ratio of 0.2, bearing five lateral and five medial transverse ranks of mixed long robust setae and very long slender simple setae, an apical cluster of six short robust setae and twelve very long slender simple setae. Telson (Figure 4): length less than width, shorter than urosomite three (0.75x), cleft 95% of length, lobes sub triangular, lateral margin almost straight, medially concave, narrowing distally to a mid distal peak bearing three small apical acuminations, lateral and medial robust setae dorsally at M0.8, and two sub apical robust setae medial to the apex, paired penicillate setules sub lateral at M0.85 and a single sub apical penicillate setule as well as one or two marginal naked setae, otherwise without dorsofacial setation.
Figure 4  *Nurina poulteri* holotype, male 'a': abdomen, third pleopod, uropods 1–3, telson.
Figure 5  *Nurina poulteri* allotype, female 'b': gnathopods 1-2, coxae 3-7 indicating coxal gills and oostegites.
two dorsomedial and five apical robust setae. 

**Third uropod:** very similar to the male holotype; inner ramus bearing a second small apical seta; outer ramus of one article, bearing five translateral clusters of robust and slender setae both laterally and medially, and six robust and six very long slender apical setae.

**Description of male 8.9 mm**

Similar to the holotype, except in the following: 

**First antenna:** primary flagellum of twenty four articles (apex lost), the first elongate, 2x article two, the accessory flagellum of four articles, extending to M0.7 of article four of the primary flagellum. 

**First gnathopod:** with a deep palmar notch. 

**Second gnathopod:** very much larger than the first, propodus enlarged - 3.5x the first. 

**Uropods.** 

**First uropod:** peduncle with four dorsolateral, two apicodorsal, two dorsomedial and one apicomedial robust setae; inner ramus bearing one dorsolateral, three dorsomedial and five apical robust setae; outer ramus bearing two dorsolateral, three dorsomedial, and five apical robust setae. 

**Second uropod:** peduncle bearing only a single apicodorsal robust seta; inner ramus with three dorsolateral, two dorsomedial, and five apical robust setae; outer ramus with one dorsolateral, three dorsomedial and five apical robust setae. 

**Third uropod:** peduncle bearing small basal and lateral facial setae, two apicodorsal and two apicomedial robust setae; inner ramus small, scale like, bearing two apical robust setae; outer ramus one articulate, with six transverse medial and lateral clusters of robust and very long slender setae, the apex with five robust and twelve very long slender setae. 

**Telson:** the right lobe bearing an additional, fifth, lateral robust seta, the left lobe without this addition.

**Distribution**

Nurina Cave N46 and cave N1327, Roe Plains Western Australia.

**Etymology**

Named for Mr Norm Poulter who was involved in the collection of specimens from both Nurina Cave and cave N1327, and without whose participation this new species would not have been described.

**Discussion**

Three caves are known on the Roe Plains, although only two of these – Nurina Cave (N46) and cave N1327 – intersect the regional water-table. Nurina Cave is located approximately 14 km south of the Hampton Scarp, old eroded sea-cliffs marking the northern extent of the Roe Plains, and approximately 30 km north of the present coastline. The elevation of the entrance is 24.8 m +/- 1.5 m above mean sea-level (Wigley and Hill, 1967). Several water quality measurements have been made in the cave: the salinity and chemical composition of the water is essentially the same as sea water, except that it is enriched with calcium (Gillieson and Spate, 1992; James et al., 1991; Lowry, 1970). Entrance to the cave is via open vertical passages. 

*N. poulteri* is abundant in the pool immediately below the entrance and, although present elsewhere in the extensive cave system, is far less abundant (Eberhard, 1999).

Cave N1327 lies approximately 6 km north-west of Nurina Cave. Groundwater pools are relatively shallow – less than 2 m – including some with a silty substrate. The physicochemistry of the water is unknown. The entrance to this cave is quite restricted and the potential for external food supply thus reduced. In this cave *N. poulteri* (as well as other aquatic invertebrates) is closely associated with intrusive tree roots (mallic - *Eucalyptus* spp.) which penetrate to a depth of approximately 25 m to reach the water-table (Eberhard, 1999). These roots appear cropped, similar to root mats at Yanchep Caves, Western Australia which are heavily grazed by a diverse community of aquatic invertebrates (Jasinska et al., 1996).

The Nullarbor region was inundated by the sea following subsidence during the early Cretaceous, the first limestones forming about 45MYA in the Middle Eocene (Lowry, 1970), with at least two periods of recession during the Oligocene and Early Miocene, followed by uplift during the Middle Miocene about 15MYA (Lowry and Jennings, 1974). Since that time, the Nullarbor Plain has not been subject to marine transgression until the Late Pliocene-Early Pleistocene when sea-level reached about 30 m above its present level. This transgression eroded the Roe Plains, and the Hampton Range scarp to the north is the old sea cliff of Late Pliocene age. The history of marine transgressions and recessions suggests that Nurina poulteri is a species derived from the stranding of a marine progenitor following one of these episodes. Other elements of the Nullarbor cave fauna, however, suggest a relict terrestrial/freshwater origin postdating the Late Pliocene-Early Pleistocene emergence of the Roe Plains either by underground dispersal from the plateau or by vicariant extinction of surface dwelling ancestors (Gray, 1973 a, b). Nevertheless, Nurina bears many similarities to marine Melita and is considered to be of marine rather than freshwater origin. Similar marine-derived taxa have been described from North West Cape, Western Australia and the Flinders Ranges, South Australia (Humphreys and Adams, 1991; Knott, 1993; Barnard and Williams, 1995; Bradbury and Williams, 1997a, b).
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REFERENCES


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Amblypomacentrus claus, a new species of damselfish (Pomacentridae) from the Banggai Islands, Indonesia

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Abstract - A new species of pomacentrid fish, Amblypomacentrus clarus, is described from 4 specimens, 26.1-40.3 mm SL from the Banggai Islands, off central-eastern Sulawesi, Indonesia. It closely resembles A. breviceps (Schlegel and Müller), the only other species in the genus. Colour pattern differences constitute the main criteria for separating the two species. The pattern of three dark bars is more highly contrasted in A. clarus, and this species lacks rows of light blue spots on the side and a yellow suffusion on the lower body, features usually evident in A. breviceps. There are also differences in lower limb gill-raker counts and tubed lateral-line scales, with 16 lower-limb rakers and 15 tubed lateral-line scales in A. clarus and usually 14-15 rakers and 16-17 tubed scales in A. breviceps. Amblypomacentrus clarus is known only from the type locality, where it is sympatric with A. breviceps, affording ready comparison of the two species.

INTRODUCTION

Damselfishes (Pomacentridae) are among the most speciose and conspicuous of all fishes inhabiting tropical and subtropical reefs. The family was reviewed by Allen (1991), who recognized 321 species in 28 genera. Since the publication of this work 16 additional species have been described (Allen, 1992, 1993, 1994, 1999; Allen and Adrim, 1992; Allen and Rajasuriya, 1995; Allen and Smith, 1992; Moura, 1995; Randall, 1994; Randall and McCosker, 1992). Four additional species await description and three others, either inadvertently omitted by Allen (1991) (Chromis dispilus Griffin) or recognized as a junior synonym [Abudefduf declivifrons (Gill) and Dischistodus darwinensis (Whitley)] have been elevated to the rank of valid species. The only other change involves Chromis neqalopis Allen, which has been placed in the synonymy of C. mirationis (Allen, 1993). With these additions and amendments, the known number of pomacentrid species now totals 344, including the new taxon described herein.

The present paper describes a new species belonging to Amblypomacentrus Bleeker, 1877 as defined by Allen (1991). The genus formerly contained a single species A. breviceps (Schlegel and Müller) inhabiting the East Indian region. The new species was observed and subsequently collected by the senior author during a marine conservation survey in the Banggai Islands off central-eastern Sulawesi in November 1998.

The methods of counting and measuring are the same as those described by Allen (1972) except the length of the dorsal and anal spines are measured proximally from the base of the spine rather than from the point where the spine emerges from the scaly sheath. The gill raker at the middle of the first branchial arch is included in the lower-limb count. The last dorsal and anal soft ray is split at the base and is counted as a single element. The fraction '1/2' appearing in the scale count above the lateral line refers to a small truncated scale at the base of the dorsal fin.

Counts and proportions appearing in parentheses apply to the paratypes. Type specimens have been deposited at Pusat Penelitian dan Pengembangan Oseanologi, Jakarta, Indonesia (NCIP) and the Western Australian Museum, Perth (WAM).

SYSTEMATICS

Amblypomacentrus clarus sp. nov.

Figure 1, Table 1

Material Examined

Holotype

NCIP 6186, 40.3 mm SL, Banggai Harbour, Banggai Island, Banggai Islands, Sulawesi, Indonesia (1°34.84'S, 123°20.0'E ), 18 m, quinaldine sulphate and hand nets, G. Allen, 3 November 1998.

Paratypes

WAM P.31497-002, 3 specimens, 26.1-34.3 mm SL, collected with holotype.
Figure 1  *Amblypomacentrus clarus*, holotype, 40.3 mm SL, photographed underwater at Banggai Island, Indonesia in 18 m depth.

Table 1 Proportional measurements of type specimens of *Amblypomacentrus clarus* as percentage of the standard length.

<table>
<thead>
<tr>
<th>Character</th>
<th>Holotype NCIP 6186</th>
<th>Paratype WAM P.31497-002</th>
<th>Paratype WAM P.31497-002</th>
<th>Paratype WAM P.31497-002</th>
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<td>34.3</td>
<td>31.5</td>
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<td>17.8</td>
<td>16.8</td>
<td>14.9</td>
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<td>30.0</td>
<td>30.2</td>
<td>33.0</td>
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<td>Snout length</td>
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<td>7.0</td>
<td>6.0</td>
<td>6.1</td>
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<td>11.4</td>
<td>12.4</td>
<td>13.4</td>
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<tr>
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<td>15.2</td>
<td>17.2</td>
</tr>
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<td>36.2</td>
<td>35.2</td>
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<tr>
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<td>58.9</td>
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<tr>
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<td>23.8</td>
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<tr>
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<td>26.8</td>
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<td>Length pelvic fin</td>
<td>32.5</td>
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<td>8.0</td>
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<td>11.1</td>
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<td>Length 6th dorsal spine</td>
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<td>16.5</td>
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<tr>
<td>Length longest dorsal ray</td>
<td>24.8</td>
<td>20.4</td>
<td>18.7</td>
<td>20.7</td>
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<td>Length 1st anal spine</td>
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<td>6.7</td>
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<td>15.5</td>
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<tr>
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<td>23.1</td>
<td>21.6</td>
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<tr>
<td>Length caudal fin</td>
<td>41.2</td>
<td>33.8</td>
<td>32.1</td>
<td>31.4</td>
</tr>
</tbody>
</table>
A new species of damselfish from Indonesia

Figure 2  *Amblypomacentrus breviceps*, about 55 mm SL, photographed underwater at Kimbe Bay, New Britain in 12 m depth.

Diagnosis
A species of the pomacentrid genus *Amblypomacentrus* with the following combination of characters: dorsal rays XIII, 10 or 11; anal rays II, 12; pectoral rays 16 or 17; gill rakers on first branchial arch 6 + 16; tubed lateral-line scales 15; colour in life white with three broad black bars, the first through eye, the second below anterior dorsal fin, and the third below last dorsal spines and first few soft dorsal rays.

Description
Dorsal rays XIII, 11 (10); anal rays II, 12; pectoral rays 17 (one paratype with 16); gill rakers on first branchial arch 6 + 16, total rakers 22; tubed lateral-line scales 15; vertical scale rows from edge of opercle to caudal fin base 27; scales above lateral-line to base of middle dorsal spines 1 1/2; scales below lateral line to anus 8.

Body depth 2.3 (2.2-2.5) in standard length; maximum body width 2.3 (2.4-2.8) in depth; head length contained 3.3 (3.0-3.3) in standard length; snout 4.6 (4.3-5.4), eye 3.1 (2.4-2.6), interorbital space 3.4 (3.4-4.3), least depth of caudal peduncle 2.0 (2.1-2.2), length of caudal peduncle 2.0 (1.9-2.0), all in head length.

Mouth oblique, terminal, the maxillary reaching to a vertical slightly beyond anterior edge of eye; teeth of jaws uniserial, incisiform with broad flattened tips at front of jaws, smaller and conical posteriorly; about 32 teeth in lower jaw and 34 in upper; single nasal opening on each side of snout; nostril with a low fleshy rim; about 20 sensory pores on each side of snout-interorbital region; preorbital and suborbital relatively narrow, the greatest depth about one-third eye diameter; ventral margin smooth, but with fine serrations posteriorly on suborbital series; a double row of sensory pores on preopercle-subopercle series; posterior margin of preopercle finely serrate; opercular series smooth except a blunt, flattened spine present on upper edge of opercle, near angle, and similar, but smaller spine on uppermost edge, just below lateral-line origin.

Scales of head and body finely ctenoid; preorbital, suborbital, snout, lips, chin, and isthmus naked; preopercle with 3 scale rows (2 primary rows and row of smaller secondary scales near lower margin).
rear margin narrowly naked; dorsal and anal fins with a basal scaly sheath; proximal two-thirds of caudal fin covered by scales; pectoral fins covered by scales basally; axillary scale of pelvic fins about twice length of pelvic spine.

Tubed lateral-line scales ending below posterior spines of dorsal fin; pits or pores present on 2 scales immediately posterior to last tubed scale; a series of 8–9 pored or pitted scales mid-laterally on caudal fin immediately posterior to last tubed scale; a series of 8–9 pored or pitted scales mid-laterally on caudal fin.

Origin of dorsal fin above third tubed scale of lateral line; spines of dorsal fin gradually increasing in length to about sixth spine, remaining spines slightly decreasing in length, except for last spine, which is slightly longer than preceding ones; outer margin of fin continuous without incisions between spines; first dorsal spine 1.7 (1.3–2.1) in second dorsal spine; second dorsal spine 1.5 in sixth dorsal spine; sixth dorsal spine 2.1 (1.8–2.1) in head; longest soft dorsal ray 1.2 (1.5–1.6) in head; length of dorsal-fin base 1.7 in standard length; first anal spine 2.9 (2.3–2.7) in second anal spine; second anal spine 2.2 (1.9–2.6) in head; longest soft anal ray 1.3 (1.4–1.8) in head; base of anal fin 2.3 (2.3–2.5) in base of dorsal fin; caudal fin emarginate with pointed lobes, the upper lobe of male holotype with short trailing filament, caudal-fin length 0.7 (0.9–1.0) in head length; pectoral fin relatively short, not quite reaching a vertical through origin of anal fin, the longest ray 1.2 (1.1–1.3) in head length; filamentous tips of pelvic fins reaching to about base of second soft anal-fin ray when depressed in male holotype, but barely reaching anal fin origin in paratypes; pelvic fin-length 0.9 (0.9–1.2) in head length.

Colour of holotype in alcohol: overall white to yellow white with three broad black bars as follows: one on head passing through eye, its maximum width 2.8 (2.4–2.5) in head length; one at level of dorsal-fin origin, tapered ventrally and extending to level of pectoral-fin base, its maximum width 1.9 (1.9–2.2) in head length; and one encompassing last dorsal spines and first few soft dorsal rays, extending to about mid side, but faintly evident to lower side, its maximum width 1.6 (1.8–2.2) in head length; upper surface of caudal peduncle and base of caudal fin faintly dusky grey; dorsal fins translucent except where interrupted by black bars; remaining fins translucent to whitish. The paratypes have a similar colouration.

Colour in life: overall white with three broad black bars as described above.

Remarks

This species is very similar to *A. breviceps*, differing mainly in live and preserved colour pattern. Juveniles are basically the same colour as adults in contrast to those of *A. breviceps*, which have a strong yellow hue on the lowermost part of the body and yellow pelvic and anal fins. The yellow hue on the lower body often persists in adults of *A. breviceps* and each scale on the side of the body has a small light blue spot, forming horizontal rows corresponding with each scale row. Moreover, the second and third dark bars of *A. breviceps* are usually linked by a broad dark band on the outer edge of the dorsal fin, in contrast to *A. clarus*, which has the two dark bars well separated. The dark bars of *A. clarus* are strongly evident in preserved specimens. The two posterior bars are as vividly contrasted as in live individuals, whereas these same bars in preserved *A. breviceps* form only abbreviated saddles on the upper back, with their extensions onto the middle of the sides barely evident. Specimens of *A. breviceps* examined from Sabah, Papua New Guinea, and Australia invariably had 16–17 tubed lateral line scales in contrast to 15 tubed scales in *A. clarus*. However, the single specimen of *A. breviceps* from the Banggai Islands (WAM P.31497-001) also had 15 tubed scales. The only other meristic difference detected is the number of lower-limb gill rakers, which usually number 16 in *A. clarus* and 14 or 15 in *A. breviceps*. The only exception was found among two lots containing six specimens of *A. breviceps* from Sabah, Malaysia examined at WAM. Two specimens had 16 lower-limb rakers, and the remainder possessed the typical count of 14–15.

*Amblypomacentrus clarius* is presently known only from the type locality, in contrast to *A. breviceps*, which is widely distributed in the Indo-Australian Archipelago. Locality records for the latter species include numerous Indonesian sites, Sabah, Philippines, New Guinea, New Britain, Solomon Islands, and northeastern Queensland. The two species were seen in close proximity in Banggai Harbour at depths between 18–25 m at the type locality of *A. clarus*. The habitat consisted of a sloping bottom of sand-silt with scant shelter in the form of scattered bottles, tyres, and other miscellaneous debris. Individuals of *A. clarius* were seen feeding a short distance above the bottom, presumably in search of planktonic food items.

It is named *clarius* (Latin: clear, distinct) with reference to the more vividly contrasted colour pattern in comparison with *A. breviceps*.

ACKNOWLEDGEMENTS

We thank Conservation International (CI) and especially Tim Werner, Director of CI’s Coastal Marine Conservation Program, for providing the opportunity to visit the Banggai Islands. This expedition was supported and jointly sponsored by Lembaga Ilmu Pengetahuan Indonesia (LIPI) and Conservation International-Indonesia.
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A new species of *Urodacus* from Western Australia, with additional descriptive notes for *Urodacus megamastigus* (Scorpiones)

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Abstract — *Urodacus mckenziei* is described from a large collection of males and a few females from the Shark Bay region of Western Australia. It is superficially similar to *U. megamastigus* L. E. Koch. *Urodacus mckenziei* and *U. megamastigus* are critically examined and a comprehensive description of *U. megamastigus* is given to complement Koch's (1977) description.

INTRODUCTION

In a major revision of the Australian scorpion fauna, Koch (1977) published a description of an unusual species of *Urodacus, U. megamastigus*, which was easily distinguished from other species of the genus by the unique morphology of the male telson. The description was based upon five specimens from two separate localities in Western Australia. Since the description of the species, only six additional specimens have been uncovered.

Amongst the scorpions collected during a major biotic survey of the Carnarvon Phytogeographic District, was a large series of specimens initially attributed to *U. megamastigus*. Detailed examination of these specimens revealed that they are specifically distinct from *U. megamastigus*, and the description of this new species is presented here. Since the Carnarvon survey, two additional female specimens have been collected and these are also described here. Additional descriptive notes are made for *U. megamastigus* to complement the original description of the species (Koch, 1977).

MATERIALS AND METHODS

Specimens were collected with the aid of 20 litre pitfall traps to which a mixture of ethylene glycol and formalin was added (see Harvey et al., in press). These were cleared at regular intervals over a 12 month period.

The majority of specimens are lodged in the Western Australian Museum, Perth (WAM), while individual paratypes are lodged in the Australian Museum, Sydney (AM), Australian National Insect Collection, CSIRO, Canberra (ANIC), Erich Volschenk collection (ESV), Museum of Victoria, Melbourne (NMV), Queensland Museum, Brisbane (QM), South Australian Museum, Adelaide (SAM) and Museum National d'Histoire Naturelle, Paris (MNHP).

Terminology and mensuration follows Vachon (1973), Hjelle (1990) and Sissom (1990) which differ from that used by Koch (1977) in several respects. *Urodacus* possess varying degrees of neobothriotaxic type “C” arrangements, possessing additional or fewer trichobothria than the basic “C” configuration (Vachon, 1973; Sissom, 1990) on the pedipalpal patella and chela. Both *U. mckenziei* and *U. megamastigus* possess additional accessory trichobothria, which make identification of various external groups difficult, particularly for *U. megamastigus*. In these cases, all identifiable trichobothria are named, while the remaining are collectively termed external accessory group (ea — patella, Ea — manus).

All specimens were examined using a Leica MZ6 stereo dissection microscope with a times two objective lens. Colouration is given relative to the “1994 Munsell Soil Color Chart”. The authors' verbal description of the colour is followed by the colour data in square brackets ie [7.5R 4/6] represents Munsell hue code '7.5R', Value number '4' and Chroma number '6'.

SYSTEMATICS

Family Urodacidae Pocock

Genus *Urodacus* Peters

*Urodacus* Peters, 1861: 511.

loctonus Thorell, 1876: 14. Type species: *loctonus manicatus* Thorell, 1876, by monotypy.

1 Deceased 30 June 1999
lodacus Pocock, 1891: 245. Type species: *lodacus darwinii* Pocock, 1891 (junior synonym of *Urodacus excellens* Pocock, 1888, by monotypy).

*Hemihoplopus* Birula, 1903: xxxiii. Type species: *Hemihoplopus yaschenkoi* Birula, 1903, by original designation.

**Type Species**

*Urodacus novaehollandiae* Peters, 1861, by monotypy.

**Diagnosis**

The genus *Urodacus* is endemic to Australia, where it is diverse in form and habitat. The genus was recently placed into its own family, *Urodacidae*, by Prendini (in press) following a revision of the Scorpionidae Latreille. Scorpions in the genus *Urodacus* are easily recognised by the following combination of characters:

- movable finger of the chelicerae with single superior subdistal tooth;
- pedipalp with $E_{1}$ ventrally placed, the remaining $E_{1}$ trichobothria being external; $D_{1}$ in the basal half on the manus; $E_{st}$ located distally; presence of only a single ventral submedian carina on metasomal segments I-IV; distal lamella of hemispermatophore without a sclerotised crest; internobasal reflection of sperm duct modified into a mating plug; ovariuterus with diverticula; sternum, longer than wide; subventral setae of tarsi spiniform; tarsi of legs I-IV with rounded, lobate laterodistal margin.

**Urodacus mckenziei** sp. nov.

Figures 1-16, 33-35, Tables 1-3

**Material Examined**

**Holotype**

$\delta$, Zuytdorp, site ZU4, Western Australia, Australia, 27°15'45.1"S, 114°09'12.9"E, wet pitfall trap, 10 January-18 May 1995, M.S. Harvey et al., WAM/CALM Carnarvon Survey (WAM 99/1111).

**Paratypes**

**Australia: Western Australia:** 16 $\delta$, same data as holotype (WAM 99/1112-1127); 7 $\delta$, same data as holotype (1 $\delta$ in each of AM KS6228; ANIC; ESV-4462; NMV K-7298; MHNP RS-7475; QM S51330; SAM NS1126); 1 $\delta$, Peron Homestead, 100 m W. of Visitors Centre, 25°50'S, 113°33'E, April 1998, T. Tischler (WAM 98/1592).

**Other Material**

**Australia: Western Australia:** 23 $\delta$, Francois Peron National Park, site PE2, 25°52'30.9"S, 113°32'59.0"E, wet pitfall trap, 17 January-25 May 1995, M.S. Harvey et al., WAM/CALM Carnarvon Survey (WAM 99/1128-1150); 10 $\delta$, Meedo Station, site MD1, 25°37'31.3"S, 114°09'2.9"E, wet pitfall trap, 12 January-17 May 1995, A. Sampey et al., WAM/CALM Carnarvon Survey (WAM 99/1151-1160); 4 $\delta$, Nanga Station, site NA2, 26°29'23.0"S, 114°03'24.3"E, wet pitfall trap, 19 January-11 May 1995, A. Sampey et al., WAM/CALM Carnarvon Survey (WAM 99/1161-1164); 4 $\delta$, Nanga Station, site NA3, 26°31'20.9"S, 114°00'08.3"E, wet pitfall trap, 19 January-12 May 1995, A. Sampey et al., WAM/CALM Carnarvon Survey (WAM 99/1165-1168); 1 $\delta$, Nerren Nerren Station, site NE2, 27°03'24.1"S, 114°09'24.6"E, wet pitfall trap, 11 May-18 August 1995, N. McKenzie, J. Rolfe, WAM/CALM Carnarvon Survey (WAM 99/1173-1177); 7 $\delta$, Zuytdorp, site ZU3, 27°15'45.9"S, 114°04'13.7"E, wet pitfall trap, 11 January-18 May 1995, M.S. Harvey et al., WAM/CALM Carnarvon Survey (WAM 99/1178); 16 $\delta$, Zuytdorp, site ZU4, 27°15'45.1"S, 114°09'12.9"E, wet pitfall trap, 16 October 1994-10 January 1995, N. McKenzie, P. West et al., WAM/CALM Carnarvon Survey (WAM 99/1179-1184); 16 $\delta$, Zuytdorp, site ZU5, 27°15'42.9"S, 114°11'36.1"E, wet pitfall trap, 10

**Table 1** Morphometric comparisons between *Urodacus megamastigus* L. E. Koch and *U. mckenziei* sp. nov.

<table>
<thead>
<tr>
<th></th>
<th><em>U. megamastigus</em></th>
<th><em>U. mckenziei</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males (n=6)</td>
<td>Females (n=1)</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carapace length</td>
<td>6.5-7.5</td>
<td>6.60</td>
</tr>
<tr>
<td>Pedipalpal patella Length</td>
<td>3.8-4.4</td>
<td>6.20</td>
</tr>
<tr>
<td>Hand length</td>
<td>11.3-13.3</td>
<td>12.40</td>
</tr>
<tr>
<td>Hand width</td>
<td>3.8-4.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Hand depth</td>
<td>3.1-3.5</td>
<td>3.20</td>
</tr>
<tr>
<td>Movable finger Length</td>
<td>6.0-7.5</td>
<td>6.80</td>
</tr>
<tr>
<td>Metasomal segment IV Length</td>
<td>5.2-7.1</td>
<td>6.20</td>
</tr>
<tr>
<td>Pectine count (left + Right)</td>
<td>39-47</td>
<td>42.30</td>
</tr>
</tbody>
</table>
A new species of *Urodacus* from Western Australia

Figures 1-10 *Urodacus mckenziei* sp. nov: 1, carapace, dorsal view; 2, carapace, lateral view; 3, metasoma I, lateral view; 4, metasoma II, lateral view; 5, metasoma III, lateral view; 6, metasoma IV, lateral view; 7, metasoma V, lateral view; 8, telson, lateral view; 9, right chelicera, lateral view; 10, pedipalp femur, dorsal view. Scale lines = 1 mm.
Figures 11-16  *Urodacus mckenziei* sp. nov.: 11, pedipalp patella, dorsal view; 12, pedipalp patella, external view; 13, pedipalp patella ventral; 14, pedipalp chela, external view; 15, pedipalp chela (manus), ventral view; 16, left hemispermatophore, ventral aspect. Scale lines = 1 mm.
A new species of *Urodacus* from Western Australia

**Table 2** Comparison between counts of external trichobothrium groups of *U. mckenziei* (n=23) and *U. megamastigus* (n=8). Ranges are given where appropriate, and following a semicolon, the most common count.

<table>
<thead>
<tr>
<th></th>
<th>Patella</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>D</td>
<td>Eb</td>
<td>esb</td>
<td>ea</td>
<td>Est</td>
<td>et</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td><em>U. mckenziei</em></td>
<td>1</td>
<td>3</td>
<td>5-7;6</td>
<td>2-4;3</td>
<td>2-5;4</td>
<td>3</td>
<td>3</td>
<td>6-8;7</td>
<td>28-31;29</td>
</tr>
<tr>
<td><em>U. megamastigus</em></td>
<td>1</td>
<td>3</td>
<td>8</td>
<td>1*</td>
<td>7-14;13</td>
<td>1*</td>
<td>1*</td>
<td>8-11;10</td>
<td>30-39;38</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Manus</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>D</td>
<td>Eb</td>
<td>Esb</td>
<td>Ea</td>
<td>Est</td>
<td>Et</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td><em>U. mckenziei</em></td>
<td>2</td>
<td>2</td>
<td>4-7;5</td>
<td>1*</td>
<td>0-2;1</td>
<td>0-1;1</td>
<td>5</td>
<td>6-7;6</td>
<td>29-33;31</td>
</tr>
<tr>
<td><em>U. megamastigus</em></td>
<td>2</td>
<td>2</td>
<td>5-7;7</td>
<td>1*</td>
<td>4-6;6</td>
<td>1*</td>
<td>5</td>
<td>10-12;11</td>
<td>39-42;41</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Fixed finger</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Db</td>
<td>Dsb</td>
<td>Dst</td>
<td>Dt</td>
<td>eb</td>
<td>esb</td>
<td>Et</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>U. mckenziei</em></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>U. megamastigus</em></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* - indicates groups with representatives obscured by accessory trichobothria (ea, Ea).


**Diagnosis**

*Urodacus mckenziei* is very easily distinguishable from other known species of *Urodacus*. It differs from all except *U. megamastigus* by the very elongate and spiny telson of the male and by the elongate and spiny fifth metasomal segment possessed by both sexes. It can be separated from *U. megamastigus* by numerous features, most noticeably by the smaller size of the whole animal (figure 36); telson elongate, but not to the almost cylindrical extreme of *U. megamastigus*; aculeus possessing a pair of very long macrosetae inserting into the aculeus basally, macrosetae almost as long as the aculeus; aculeus very stout and strongly curved in *U. mckenziei*, differing from the more elongate and less curved aculeus of *U. mckenziei*. The lateral margins of the carapace are markedly convergent anteriorly, differing from the slightly convergent sides of *U. megamastigus*. External and ventral trichobothria counts of the pedipalp manus and patella are generally fewer in *U. mckenziei* than in *U. megamastigus*, particularly with respect to eb, ca, v, Ea, V groups (see Table 2). The enlarged peg-like macrosetae on the inner tarsal margins of legs III and IV number 6-7 and 6-8 respectively for *U. mckenziei* and 9-10 and 9-11 respectively for *U. megamastigus* (see Table 3).

**Table 3** Comparison of male peg-like tarsal seta counts for right legs of *U. mckenziei* males (n=23) and *U. megamastigus* (n=5).

<table>
<thead>
<tr>
<th></th>
<th>Tarsus I</th>
<th>Tarsus II</th>
</tr>
</thead>
<tbody>
<tr>
<td>External</td>
<td>6-8</td>
<td>6-8</td>
</tr>
<tr>
<td>Internal</td>
<td>5-7</td>
<td>6-7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tarsus III</td>
<td>7-9</td>
<td>7-9</td>
</tr>
<tr>
<td>External</td>
<td>6-7</td>
<td>6-8</td>
</tr>
<tr>
<td>Internal</td>
<td></td>
<td>9-11</td>
</tr>
</tbody>
</table>

**Description**


Carapace (Figures 1 and 2): generally covered with numerous fine and rounded granules, median ocular area very finely shagreened; frontal notch shallow, with frontal lobes conspicuously truncate, their anterior margins almost straight; median furrow present. Two corneae in each lateral ocular tubercle, anterior of which being much larger than posterior (Figure 2).

Mesosoma: yellowish [10YR 7/6] with a darker [10YR 5/3] medial band, the heart discernable through the cuticle; tergites with many fine granules, otherwise shagreened; no median or lateral carina present. Sternites: surface smooth, except for extreme lateral regions which contain few (posteriorly) to numerous (anteriorly) small rounded granules; posterior margins smooth and slightly concave. Spiracles are small, diagonal and moderately elongate.

Sternum: sub-pentagonal, wider than long with a furrow running medially through the posterior half. Genital operculum wider than long, divided in males and fused in females. Male genital papillae protrude from beneath the operculum.

Metasoma (Figures 3–8): colouration darker yellowish brown [7.5YR 5/6]. Male metasomal segments I–IV with dorsal, dorsolateral, ventral and
ventromedian carina, dorsal carina not terminating in large spines. Dorsal and dorsolateral carina of metasomal segments I–III with irregularly spaced large, sharp granules, metasoma IV with numerous large sharp granules and with weekly developed dorsolateral carina; remaining carina non-granular and defined by conspicuous edge uniting flat surfaces. Metasomal segment V very elongate, more than 6 times longer than deep in males, shorter in females. Ventrolateral and posterior transverse carina with numerous large to small posteriorly directed spine-like granules; numerous macrosetae along lateral and ventral margins of segment V, posterior dorsal margin produced into a lobe. Telson (Figure 8): very elongate, longer than carina with numerous large to small posteriorly metasomal segments I–III with irregularly spaced spine-like granulations (varying in size from large expanded but not bulbous, possessing numerous metasomal segments I–IV; vesicle moderately posterior dorsal margin produced into a lobe. along lateral and ventral margins of segment V, directed spine-like granules; numerous macrosetae females. Ventrolateral and posterior transverse than 6 times longer than deep in males, shorter in surfaces. Metasomal segment V very elongate, more and defined by conspicuous edge uniting flat dorsolateral carina; remaining carina non-granular large, sharp granules, metasoma IV with numerous in large spines. Dorsal and dorsolateral carina of ventromedian carina, dorsal carina not terminating in small dorsal spines; claws of unequal length with anterior claw noticeably longer than posterior claw especially on legs III and IV. Two rows of stout spiniform setae present on the ventrolateral margins of tarsi, the counts of which are summarised in Table 1.

Legs: pale yellow brown [YR10 8/6] with reddish brown [10R 5/8] articulating points; tarsomere of legs I and II with four large and one small dorsal spines; claws of unequal length with anterior claw noticeably longer than posterior claw especially on legs III and IV. Two rows of stout spiniform setae present on the ventrolateral margins of tarsi, the counts of which are summarised in Table 1.

Hemispermatophore as shown in Figure 16.
Pectines: δ, 16–25; ξ, 14; with the exception of tooth counts, the pectines are typical for the genus and not sexually dimorphic.

Remarks

Urodacus mckenziei has only been collected from the Carnarvon region of Western Australia.

Etymology

The species is named for Norman I. McKenzie in appreciation of his contributions to biogeography in Australia.

Urodacus megamastigus L.E. Koch
Figures 17–35, Tables 1–3


Material Examined

Holotype
δ, Mundindiwi, Western Australia, Australia [23°50'S, 120°10'E], 8 April 1963, A. Snell (WAM 66/368).

Paratypes
Australia: Western Australia: 2 δ, same data as holotype except 1963 (WAM 68/366-367); 1 δ, 1 ξ, Walgun Station [23°12'S, 120°43'E], 21 May 1971, A.M. Douglas (WAM 71/1784-1785).
A new species of *Urodacus* from Western Australia

*Urodacus megamastigus* L.E. Koch: 17, carapace, dorsal view; 18, carapace, lateral view; 19, metasoma I, lateral view; 20, metasoma II, lateral view; 21, metasoma III, lateral view; 22, metasoma IV, lateral view; 23, metasoma V, lateral view; 24, telson, lateral view; 25, right chelicera, lateral view. Scale lines = 1 mm

**Other Material**

**Australia:** Western Australia: 1 ♂, Millstream [21°35'S, 117°04'E], low spinifex over gravel, 8 May 1986, D. King, J. Gardner, M. Calver (WAM 99/1208); 1 ♂, Meridian (wildcat oilwell), 30 miles E. of Willara Hill, Great Sandy Desert, ca. 19°00'S, 122°22'E, 25 May 1982, A.M. Douglas (WAM 99/1209); 1 ♂, Newman area, ca. 23°21'S, 119°44'E, April 1984, D. Kaljuste (WAM 97/3148); 3 ♂, Mt Brockman Station, site 30, 22°18'27"S, 117°15'27"E, 11 May 1999, pitfall traps, P.J. West (WAM 99/1211-1213).

**Diagnosis**

*Urodacus megamastigus* is one of the most striking representatives of the genus. It is most similar to *U. mckenziei* but can be separated using several features including: the much larger adult size of *U. megamastigus*; extremely elongate metasomal segment V, more than seven times longer than deep in males; the telson is also more elongate, to the extent of being almost cylindrical in males, females with telson more typical for the genus; aculeus stout and sharply curved in the distal half. *Urodacus megamastigus* (Figure 36) possesses more numerous
Figures 25-32  *Urodacus megamastigus* L.E. Koch: 26, pedipalp femur, dorsal view; 27, pedipalp patella, dorsal view; 28, pedipalp patella, external view; 29, pedipalp patella ventral; 30, pedipalp chela, external view; 31, pedipalp chela (manus), ventral view; 32, left hemispermatophore, ventral aspect. Scale lines = 1 mm.

trichobothria on the pedipalps patella and manus (Table 2); tarsi of legs III and IV also with more numerous spiniform setae on the ventrolateral margins (Table 3).

**Description**

Colouration: mostly uniform yellow brown [10YR 4/4], carapace with slightly darker areas only in the immediate vicinity of the lateral and median eyes. Legs and metasomal segments paler yellowish brown [10YR 5/6] external margin of femora, patellae and metatarsi with distinct red [2.5YR 3/6] articulating point.

Carapace (Figures 17, 18): almost entirely covered with numerous fine granules; frontal notch shallow; frontal lobes truncate, with anterior margins slightly convex. Median furrow moderately deep; lateral eyes, in low tubercles, each with two corneae, the anterior being considerably larger than the posterior. Median ocular tubercle well
A new species of *Urodacus* from Western Australia

developed, and finely shagreened.


Sternum: sub-pentagonal, wider than long; possessing a moderate furrow placed in the median posterior half. Genital operculum; divided in mature males, with genital papillae protruding from beneath; fused in females.

Metasoma (Figures 19–24): dorsal, dorsolateral, ventral and ventromedian carina present on segments I–V although incomplete on segment V, losing integrity in the distal quarter. Segments I–IV mostly smooth with few moderate rounded granules confined to carina. Male; metasoma V very elongate and possessing numerous setae laterally and ventrally; telson (Figure 5) very elongate, longer than each of metasomal segments I–IV; covered ventrally and ventromedially with elongate, spine-like granulations; aculeus short and thick, distally hooked. Female metasoma much shorter than that of male, telson and metasoma V moderately elongate but not to the extent of the male, granulation and setation of metasoma V similar to that of the male, but telson without large granules.

Chelicerae (Figure 25): teeth without secondary serrations. Fixed finger with proximal edge of sub-basal tooth slightly incurved; basal tooth often slightly bilobed and fused with median tooth to form a tri-cusp.

Pedipalp reddish yellow [7.5YR 6/8] with darker sclerotised carinal granules and chelal fingers. Femur (Figure 26): with irregularly scattered granules on anterior and posterior margins; with 3 trichobothria, i, d and e. Trichobothrium d positioned slightly more proximal (almost medially) to femur anterior margin than e. Flat surfaces with evenly scattered, fine round granulations.

Patella (Figures 27–29, Table 2): with scattered granules on anterior and posterior margins; total of 30–39 trichobothria present, usually 38; d, displaced externally and along with eb, esb, est and e, form a distinct line in the dorsal half; the presence of numerous accessory trichobothria make defining all but the external basal group (eb) e, est and esb, impossible on the external surface. Trichobothria counts are summarised in table 2. Chela (Figures 30–31, Table 2): hand narrow and moderately flat; internal surfaces with moderately granulated keel; dorsal surface with faint, smooth keel. Fingers moderately long; both fingers with numerous small teeth in several rows; trichobothria total of 39–42, usually 41 Db very basal on the hand and below the intermediary carina, Dt anterior to Db, but still in the basal half of the hand and placed on the dorsal side of the intermediary carina. Fixed finger with: dt placed in the base of the distal quarter of the

Figure 33 Map showing known distributions of *Urodacus megamastigus* L.E. Koch and *Urodacus mckenziei* sp. nov.
**Figures 34–35** Urodacus mckenziei sp. nov. telson: 34, female; 35, male. Scale lines = 2 mm.

finger, \( db, dsb \) and \( dst \) sub-equally spaced, \( dst \) closer to \( dt \) than to \( dsb \), \( db \) very basal on the finger; \( est \) placed medially on the finger with \( et \) more proximal to \( esb \) than the distal end of the finger, \( eb \) and \( esb \) in the basal quarter of the finger, \( esb \) closer to \( eb \) than to \( est \).

Legs: metatarsus I with four large and one small dorsal spines; lateroapical margin of pedal tarsi produced into rounded lobes; claws sub-equal in length.

Hemispermatophore as shown in Figure 32.

Pectines: \( 5, 19-25 \); \( 9, 12-13 \); usual for genus and with exception of tooth counts, are not sexually dimorphic.

**Remarks**

Urodacus megamastigus is only known from five localities (Figure 33), and the six new specimens listed above extend its known range further to the north. Its distribution is more northern and eastern than that of U. mckenziei. This species is unusual amongst species of Urodacus in the extreme level of sexual dimorphism exhibited on the metasoma.
A new species of *Urodacus* from Western Australia

![Graph depicting size differences between *Urodacus megamastigus* and *U. mckenziei*.](image)


Manuscript received 18 August 1999; accepted 4 February 2000.

Description of a new subgenus and species of the fish genus *Congrogadus* Günther from Western Australia (Perciformes: Pseudochromidae)

Anthony C. Gill¹, Randall D. Mooi² and J. Barry Hutchins³

¹Department of Zoology, The Natural History Museum, Cromwell Road, London SW7 5BD, U.K.
²Vertebrate Zoology Section, Milwaukee Public Museum, 800 West Wells Street, Milwaukee, Wisconsin 53233, U.S.A.
³Department of Aquatic Zoology, Western Australian Museum, Francis Street, Perth, Western Australia 6000, Australia

Abstract — *Congrogadus xointerbottomi* is described from Middle Mangrove Island, West Pilbara Islands, and Exmouth Gulf in Western Australia. It is assigned to a new subgenus, *Pilbaraichthys*, which is distinguished from other congrogadine genera and subgenera by the following combination of characters: dorsal-fin rays 1,57-61 (usually 1,59 or 1,60); anal-fin rays 47-50 (usually 48 or 49); pelvic fins and their girdles absent; dark spot on operculum, none on shoulder; gill membranes fused ventrally, with posterior margin free from isthmus; lateral line in single, short anterodorsal section; teeth in outer row of dentary and premaxilla 14-21; and check with short dark bar extending from posteroventral edge of eye (at about 5 o'clock position) towards lower (anterior) tip of preopercle.

INTRODUCTION

The Pseudochromidae is an Indo-Pacific family of small, reef-associated fishes. The family is currently divided into four subfamilies: Anisochrominae, Congrogadinae, Pseudochrominae and Pseudoplesiopinae (Godkin and Winterbottom, 1985; Gill, in press). Unlike the more or less perch-like members of the Anisochrominae, Pseudochrominae and Pseudoplesiopinae, commonly known as dottybacks, the Congrogadinae are eel-like in body form, and frequently called eelblennies. The Congrogadinae were revised by Winterbottom (1986), who recognised nine genera with 19 species. Three additional species, all from southern Oman, have been described since the publication of Winterbottom's revision, two by Winterbottom and Randall (1994) and one by Winterbottom (1996).

In May 1996, the present authors surveyed shore fishes from the West Pilbara Islands, Western Australia. Among the fishes collected was a single sample of a distinctive new congrogadine species of the genus *Congrogadus* Günther, 1862. A search of museum collections revealed an additional nine specimens, collected at several localities in Exmouth Gulf, Western Australia. We herein describe the new species and assign it to a new subgenus.

MATERIALS AND METHODS

Nomenclature of head pores follows Winterbottom (1986), except for the series of pores in the posterior temporal area (Figures 1–2): supraleithral (= “posterior temporal” or “posttemporal” of Winterbottom, 1986) in the supraleithrum just anterior to the first lateral-line scale; posttemporal (= “anterior temporal,” in part, of Winterbottom, 1986) in the posttemporal; anterior temporal (= “anterior temporal,” in part, of Winterbottom, 1986) between the junction of the posttemporal and the lateral extrascapula. This terminology permits homologous comparison of head pore patterns between and within pseudochromid subfamilies. Osteological details were determined from x-radiographs and two paratypes (in BMNH 1999.9.21.4-5) that were cleared and counter-stained for cartilage and bone following the methods of Potthoff (1984). Cranial length was measured following Godkin and Winterbottom (1985). Vertebral counts are presented in the form precaudal + caudal; the latter are defined as vertebrae bearing a haemal spine, and include the terminal urostylar complex. Terminology of ribs and intermuscular bones follows Gill (1998). Other methods of counting and measuring follow Winterbottom (1986). Institutional codes follow Leviton et al. (1985). Counts and measurements are given as values or value ranges for all type specimens, followed, where different, by values for the holotype in parentheses. Where counts were recorded bilaterally, both counts are presented for the holotype, separated by a slash; the first count given is the left count. Frequency
Table 1  Frequency distributions for selected meristic characters of Congrogadus (Pilbaraichthys) winterbottomi. * indicates characters for which bilateral counts are included.

<table>
<thead>
<tr>
<th>Character</th>
<th>Middle Mangrove I.</th>
<th>Exmouth Gulf</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segmented dorsal rays</td>
<td>57</td>
<td>58</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>61</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>63</td>
<td>×</td>
<td>S.D.</td>
</tr>
<tr>
<td>Middle Mangrove I.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Exmouth Gulf</td>
<td>–</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
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<table>
<thead>
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<th>Character</th>
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<th>Exmouth Gulf</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segmented anal rays</td>
<td>47</td>
<td>48</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>×</td>
<td>S.D.</td>
</tr>
<tr>
<td>Middle Mangrove I.</td>
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<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Exmouth Gulf</td>
<td>–</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>12</td>
<td>11</td>
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<th>Total</th>
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<td>11</td>
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</tr>
<tr>
<td></td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Caudal Vertebrae</td>
<td>5</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Tube lateral line scales*</td>
<td>26</td>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>30</td>
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<td>32</td>
<td>33</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>35</td>
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<td>S.D.</td>
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<td>Middle Mangrove I.</td>
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<td>6</td>
</tr>
<tr>
<td>Exmouth Gulf</td>
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<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>3</td>
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<th>Character</th>
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<th>Exmouth Gulf</th>
<th>Total</th>
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<td>Upper gill rakers</td>
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<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>×</td>
<td>S.D.</td>
</tr>
<tr>
<td>Lower gill rakers</td>
<td>2</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>×</td>
<td>S.D.</td>
</tr>
<tr>
<td>Middle Mangrove I.</td>
<td>–</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Exmouth Gulf</td>
<td>–</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
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<table>
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<th>Character</th>
<th>Middle Mangrove I.</th>
<th>Exmouth Gulf</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Total gill rakers</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>×</td>
<td>S.D.</td>
</tr>
<tr>
<td>Pseudobranch filaments</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>10</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle Mangrove I.</td>
<td>–</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Exmouth Gulf</td>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>5</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Character</th>
<th>Middle Mangrove I.</th>
<th>Exmouth Gulf</th>
<th>Total</th>
</tr>
</thead>
</table>
| AMS 1.26723-051 (49.3 mm SL cleared and stained), AMS 1.26723-052 (18.7 mm SL cleared and stained), AMS 1.26723-057 (135.0 mm SL cleared and stained), BMNH 1847.721.67-69 (ca. 147 mm SL cleared and stained), WAM P.31013-025 (183.0 mm SL).

**SYSTEMATICS**

Family Pseudochromidae Müller and Troschel, 1849

Subfamily Congrogadinae Günther, 1862
A new subgenus and species of Pseudochromidae

Genus Congrogadus Günther, 1862
Subgenus Pilbaraichthys nov.

Type Species
Congrogadus winterbottomi sp. nov.

Diagnosis
Pilbaraichthys is distinguished from other congrogadine genera and subgenera by the following combination of characters; dorsal-fin rays 1,57–61 (usually 1,59 or 1,60); anal-fin rays 47–50 (usually 48 or 49); pelvic fins and their girdles absent; dark spot on operculum, none on shoulder; gill membranes fused ventrally, with posterior margin free from isthmus; lateral line in single, short anterodorsal section; teeth in outer row of dentary and premaxilla 14–21; and cheek with short dark bar extending from posterodorsal edge of eye (at about 5 o’clock position) towards lower (anterior) tip of preopercle.

Relationships
The following external characters place Pilbaraichthys in the genus Congrogadus (see Winterbottom, 1986): no ocellated spot on shoulder (spot on operculum); unbranched caudal-fin rays absent; 57 or more segmented dorsal-fin rays; 47 or more anal-fin rays; and lateral line in a single, short anterodorsal section. The first two characters are autapomorphic for the genus. Godkin and Winterbottom (1985) listed six osteological autapomorphies for the genus: quadrate narrow (narrow in Pilbaraichthys; Figure 3); posterior extension of quadrate longer than plate-like portion (posterior extension considerably longer than plate-like portion in Pilbaraichthys; Figure 3); ectopterygoid extending well beyond posterior

Figure 1  Posterior head pores (in black) and associated superficial osteology of Congrogadus (Pilbaraichthys) winterbottomi, BMNH 1999.9.21.4-5, 71.5 mm SL, paratype. (The presence of an anterior temporal and two posttemporal pores is exceptional for the species.) ATP, anterior temporal pore; EPOC, epioccipital; FR, frontal; ITP, intertemporal pores; LEX, lateral extrascapula; LLSC1, lateral-line scale 1; PAR, parietal; PARP, parietal pores; POP, preopercle; POPP, preopercular pores; PT, posttemporal; PTER, pterotic; PTP, posttemporal pores; SCL, supracleithrum; SCLP, supracleithral pore; SOC, supraoccipital. Scale bar = 1 mm.
A.C. Gill, R.D. Mooi, J.B. Hutchins

margin of plate-like portion (present in Pilbaraichthys; Figure 3); dorsal head of sympletic double (double in Pilbaraichthys; Figure 3); coronoid process of angulo-articular (not of the dentary as incorrectly stated by Godkin and Winterbottom, 1985, pp. 662, 667; correctly illustrated, however, in their fig. 6B) bilobed (bilobed in Pilbaraichthys; Figure 3); and lower jaw length greater than 76% cranial length (79-95% in Pilbaraichthys).

Godkin and Winterbottom (1985) recognised two subgenera in Congrogadus, which had previously been considered separate genera: Congrogadus, with two species, C. hierichthys Jordan and Richardson 1908 from the Sulu Sea, Philippines, and C. subducens Günther 1862 from the West Pacific and eastern Indian Ocean; and Congrogadooides Borodin 1933, with three species, C. amplimaciilatus (Winterbottom, 1980) from the Gulf of Carpentaria, Australia, C. malayanus (Weber, 1909) from the Aru Islands to Torres Strait, Australia, and C. spinifer (Borodin, 1933) from northwestern Australia.

Godkin and Winterbottom (1985) listed two synapomorphies to link the two species of the subgenus Congrogadus: medial swelling on palatine (absent in Pilbaraichthys; Figure 3); and lower jaw length greater than 94% cranial length (79-95% in Pilbaraichthys). Godkin and Winterbottom also noted that Congrogadus has numerous teeth on the premaxilla and dentary, the outer row teeth 18-40 and 19-43, respectively. The premaxillary and dentary teeth are less numerous in Pilbaraichthys, the outer row teeth 14-21 and 14-21, respectively. Halimuraenoides also has numerous premaxillary and dentary teeth, but assuming the relationships proposed by Godkin and Winterbottom are accurate, the condition is interpreted to be independently derived (and thus an autapomorphy of Halimuraenoides and of the subgenus Congrogadus).

Godkin and Winterbottom (1985) listed three synapomorphies linking the three species of the subgenus Congrogadooides: medial process on anterior head of maxilla with constricted waist (present in Pilbaraichthys; Figure 4); well-defined white spots on body (absent in Pilbaraichthys); and gill membranes fused ventrally to isthmus (free posteriorly from isthmus in Pilbaraichthys; Figure 2). Mooi et al. (1990) proposed an additional synapomorphy linking the three species of Congrogadooides: predominance of three-armed hooks

![Figure 2](image-url) Cephalic pigmentation and cephalic sensory pores in Congrogadus (Pilbaraichthys) winterbottomi, WAM P.31582-001, 85.1 mm SL, holotype. AlOP, anterior interorbital pore; DENP, dentary pores; ITP, intertemporal pore; LLP, lateral-line scale pores; NASP, nasal pores; PARP, parietal pores; PIOP, posterior interorbital pore; POPP, preopercle pores; POTP, posterior otic pore; PTP, posttemporal pore; SCLP, supracleithral pore; SOBP, suborbital pores; SOTP, suprotic pore. Scale bar = 2 mm. Arrow indicates anterior extent of predorsal scales.
A new subgenus and species of Pseudochromidae

Figure 3  Lateral view of lower jaw and suspensorium in Congrogadus (Pilbaraichthys) winterbottomi, BMNH 1999.9.21.4-5, 71.5 mm SL, paratype, right side reversed. ANGART, angulo-articular; DEN, dentary; ECTPT, ectopterygoid; HYOM, hyomandibula; INTHY, interhyal; IOP, interopercle; MESPT, mesopterygoid; METPT, metapterygoid; OP, opercle; PAL, palatine; POP, preopercle; QUAD, quadrate; RETART, retro-articular; SOP, subopercle; SYM, symplectic. Cartilage shown in coarse stipple. Scale bar = 2 mm.

on egg surfaces. Unfortunately, however, we are unable to determine whether this character is present in Pilbaraichthys, as none of our specimens is gravid.

Thus Pilbaraichthys lacks all three autapomorphies of the subgenus Congrogadus, and possesses one of the four autapomorphies of the subgenus Congrogadoiades (and we are unable to comment on one of the four autapomorphies, which involves egg-surface morphology). The presence in both of the medial process on anterior head of maxilla with constricted waist suggests a sister relationship between Pilbaraichthys and Congrogadoiades. However, support for this relationship is weak, as Godkin and Winterbottom (1985) noted that among congrogadines the medial process on the anterior head of the maxilla has a constricted waist in Haliophis and in the subgenus Congrogadus, though to a lesser degree than that shown by Congrogadoiades (and by Pilbaraichthys).

A character suggesting a sister relationship between Pilbaraichthys and the subgenus Congrogadus, is the presence in both of a posterior otic pore (Figure 2), which is absent in

| Table 2  Morphometric values for Congrogadus (Pilbaraichthys) winterbottomi expressed as a percentages of standard length (SL). |
|-----------|--------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| mm SL     | Holotype           | Paratypes       | Paratypes       | Paratypes       | Paratypes       | Paratypes       | Paratypes       | Paratypes       |
|           | 85.1               | 66.1–66.9       | 70.1–77.6       | 80.0–89.2       | 92.5–97.5       | 101.4–107.3     | 111.5–119.0     |                 |
| n         | 3                  | 6               | 7               | 2               | 4               | 4               |                 |
| Soft dorsal-fin base | 79.2             | 76.9–78.8       | 76.6–78.9       | 76.4–79.8       | 78.3–79.9       | 78.7–80.9       | 78.8–80.1       |
| Anal-fin base        | 62.6             | 62.4–62.9       | 61.3–63.4       | 62.2–66.0       | 63.0–63.1       | 62.6–66.0       | 63.7–66.1       |
| Snout to 1st dorsal | 19.3             | 19.9–21.3       | 19.8–20.7       | 18.5–19.9       | 19.1–19.2       | 18.5–19.8       | 17.1–17.9       |
| Snout to soft dorsal| 20.7             | 21.1–22.8       | 21.4–22.7       | 19.6–20.9       | 20.5            | 19.8–20.6       | 18.7–19.4       |
| Snout to anal origin| 36.5             | 36.0–37.7       | 36.2–38.0       | 36.1–37.1       | 36.4–36.9       | 34.3–35.6       | 33.4–34.5       |
| Head length         | 14.3             | 15.0–16.3       | 14.4–15.7       | 12.8–15.0       | 14.2–14.4       | 13.4–13.9       | 12.3–13.3       |
| Depth at parietal   | 8.0              | 7.8–8.6         | 7.9–8.7         | 7.8–8.2         | 8.3             | 7.8–8.5         | 7.7–8.1         |
| Depth at anal origin| 10.1             | 9.4–10.6        | 9.4–10.7        | 10.1–11.0       | 10.9–11.1       | 9.4–10.9        | 9.0–10.3        |
| Eye diameter        | 3.3              | 3.4–3.8         | 3.4–3.8         | 3.0–3.4         | 2.8–3.1         | 2.6–3.0         | 2.4–2.8         |
| Snout length        | 3.6              | 3.7–4.1         | 3.4–3.9         | 3.3–3.8         | 3.6             | 3.2–3.6         | 3.2–3.4         |
| Interorbital width  | 1.2              | 1.2–1.4         | 1.1–1.4         | 1.1–1.4         | 1.3             | 1.2–1.4         | 1.2–1.4         |
| Upper jaw length    | 5.3              | 5.2–5.7         | 5.0–5.7         | 4.9–5.4         | 5.1–5.3         | 5.2–5.4         | 5.0–5.1         |
| Lower jaw length    | 9.3              | 9.6–10.6        | 9.4–9.9         | 9.0–9.6         | 9.2–9.5         | 8.9–9.1         | 8.4–8.9         |
| Pectoral length     | 5.3              | 5.7–5.8         | 5.4–5.8         | 5.0–5.6         | 5.6–5.8         | 5.3–5.9         | 5.5–5.9         |
Congrogadoides. Among congrogadines a posterior otic pore is otherwise present only in Halidesmus and Halimuraenoides. However, it is also present in various other pseudochromids, including the immediate two outgroups to the Congrogadinae (Gill and Edwards, 1999). Based on the relationships proposed by Godkin and Winterbottom (1985), the presence of a posterior otic pore is considered to be apomorphic in the genus Congrogadus, and a potential synapomorphy between Pilbaraichthys and the subgenus Congrogadus.

Godkin and Winterbottom (1985: table 1) also indicated that Congrogadoides differs from Congrogadus in lacking a supraotic pore. However, this observation is erroneous, as all species of both subgenera have a supraotic pore (e.g., see Winterbottom, 1986). Pilbaraichthys also possesses a supraotic pore.

A character suggesting a relationship between Pilbaraichthys and C. subducens (type species of Congrogadus) to the exclusion of C. hierichthys is the usual presence of two intertemporal pores, one at the junction of the pterotic and the lateral extrascapula, and the other in the pterotic just behind the preopercular canal (Figures 1–2). However, this character provides, at best, weak support for a sister relationship between the two taxa, because occasional specimens of certain other congrogadine species (i.e., C. malayanus, C. hierichthys, Halidesmus polytretus, Halimuraena hexagonata and Halimuraenoides isostigma) may also have two intertemporal pores. The other character evidence noted above supporting a sister relationship between C. subducens and C. hierichthys likewise refutes a relationship between Pilbaraichthys and C. subducens.

Justification for erection of new subgenus

We have erected Pilbaraichthys because we lack convincing evidence to place C. winterbottomi in either of the other existing subgenera (the monophyly of both of which is supported by unique autapomorphies). Therefore, its inclusion in either subgenus would possibly render that subgenus paraphyletic (and, in the case of Congrogadoides, undiagnosed by external characters). Moreover, the erection of Pilbaraichthys will ultimately lead to greater nomenclatural stability because future phylogenetic work that allows resolution of a sister relationship for C. winterbottomi either to Congrogadoides or Congrogadus (the two opposing hypotheses suggested by current evidence) or to a clade consisting of both Congrogadoides and Congrogadus will not affect its subgeneric classification.

An alternative to the erection of Pilbaraichthys would be to discard subgeneric ranking within the genus Congrogadus. However, this classification would ignore the obvious morphological differences between Congrogadus and Congrogadoides (which, as noted above, had been regarded as separate genera prior to Godkin and Winterbottom, 1985) as well as the strong character support for their monophyly.

Etymology

A combination of “Pilbara” and the Greek “ichtys” (fish), alluding to its distribution along the south-western portion of the Pilbara district.

Congrogadus (Pilbaraichthys) winterbottomi sp. nov.

Pilbara Eelblenny

Figures 1–7, Tables 1–2

Holotype

WAM P.31582-001, 85.1 mm SL, Western Australia, Middle Mangrove Island, 21°29.260'S 115°21.955'E, tidal pool in limestone reef with Sargassum and mainly sand and mud bottom (very little coral), 0–0.4 m, R.D. Mooi, A.C. Gill and J.B. Hutchins, rotenone and dipnet, 10 May 1996 (field number RDM 96-10).

Paratypes

AMS L39770-001, 2: 66.9–74.3 mm SL, collected with holotype; BMNH 1999.9.21.1-3, 3: 77.6–115.4 mm SL, collected with holotype; BMNH 1999.9.21.4-
A new subgenus and species of Pseudochromidae

Figure 5 Congrogadus (Pilbaraichtliys) winterbottomi, WAM P.31582-001, 85.1 mm SL, holotype, Middle Mangrove Island, Western Australia. Photograph by P. Hurst.

5, 2: 71.5–84.5 mm SL (cleared and stained), collected with holotype; CSIRO H5237-01, 92.5 mm SL, collected with holotype; MPM 32574, 5: 61.3–101.8 mm SL, collected with holotype; NTM S.14970-001, 80.9 mm SL, collected with holotype; QM L31415, 107.3 mm SL, collected with holotype; ROM 71992, 2: 85.3–107.0 mm SL, collected with holotype; SAM A F9302, 81.5 mm SL, collected with holotype; USNM 358035, 97.5 mm SL, collected with holotype; WAM P.31017-022, 3: 71.8–115.7 mm SL, Exmouth Gulf, Tent Island, 21°59'S 114°30'E, rock pool, J.B. Hutchins and S.M. Morrison, rotenone, 18 August 1995; WAM P.31018-012, 4: 66.8–119.0 mm SL, Exmouth Gulf, 4 km N of Tubridgi Point, 21°50’S 114°39’E, rock pool, J.B. Hutchins and S.M. Morrison, rotenone, 19 August, 1995; WAM P.31013-046, 2: 66.1–111.5 mm SL, Exmouth Gulf, NW tip of Burnside Island, 22°06’S 114°31’E, rock pool, J.B. Hutchins and S.M. Morrison, rotenone, 16 August 1995.

Diagnosis
As for subgenus.

Description
Morphometrics (based on 85.1 mm SL holotype and 26 paratypes, 66.1–119.0 mm SL; Table 2): soft dorsal-fin base 76–81 (79) % SL; anal-fin base 61–66 (63) % SL; snout tip to origin of first dorsal fin 17–21 (19) % SL; snout tip to origin of soft dorsal fin 19–23 (21) % SL; snout tip to origin of anal fin 33–38 (37) % SL; head length (HL) 12–16 (14) % SL; head depth at parietal commissure 8–9 (8) % SL, 52–66 (56) % HL; body depth at anal-fin origin 9–11 (10) % SL, 61–80 (70) % HL; eye diameter 2–4 (3) % SL, 19–25 (23) % HL; snout length 3–4 (4) % SL, 23–27 (25) % HL; bony interorbital 1 % SL, 7–11 (8) % HL; upper jaw length 5–6 (5) % SL, 34–41 (37) % HL; lower jaw length 8–11 (9) % SL, 61–71 (65) % HL; pectoral-fin length 5–6 (5) % SL, 34–45 (37) % HL.

Dorsal fin 1,57–61 (1,59), all segmented rays branched; anal fin 47–50 (48), all rays branched; pectoral fins 10–11 (10/10), upper and lower 0–1 ray unbranched, other rays branched (all rays branched in holotype); pelvic fins and girdle absent; caudal fin with five dorsal and five ventral branched rays, and no unbranched rays. Caudal fin fully connected by membrane to last ray of dorsal and anal fins. Vertebræ 15–16 + 48–50 = 63–65 (16 + 48); ribs present on precaudal vertebrae 3 through 5–6 (5); epineural bones present on precaudal vertebrae 1 through 4–6 (5). Caudal skeleton (Figure 6): epurals 1; parhypural without hypurapophys, fused to hypurals 1 through 4 and to compound urostylex complex; hypural 5 absent. A section of adductor mandibulae fused to A section (similar to C. subducens, see Godkin and Winterbottom, 1985: fig. 2C).

Cephalic sensory pore openings (Figures 1–2; all pores bilateral unless otherwise indicated): nasal usually two, one pore just posterior to upper lip, second pore just above posterior nostril, third pore present unilaterally in three paratypes and bilaterally in one paratype in middle of nasal bone adjacent to anterior nostril; anterior interorbital usually one, pore absent unilaterally in three paratypes and two pores present unilaterally in one paratype; median (unpaired) posterior interorbital one; supracoic usually one, two pores unilaterally in two paratypes; posterior otic usually one, pore absent unilaterally in two paratypes; suborbital usually eight, nine unilaterally in two paratypes; preopercular usually seven, six unilaterally in two paratypes; dentary usually four, nine unilaterally in two paratypes; intertemporal usually two, one unilaterally in six paratypes, one bilaterally in one paratype; parietal one unpaired median pore and usually one paired lateral pore, two pores bilaterally in one paratype; anterior temporal usually absent, one unilaterally in one paratype, one bilaterally in one paratype; posttemporal usually one, two unilaterally in ten paratypes; supracleithral one.

Gill membranes fused together ventrally but free posteriorly from isthmus (Figure 2); branchiostegal rays 6; outer (anterior) gill rakers on first arch 1–4 + 9–12 = 10–16 (3 + 10); pseudobranch filaments 6–10 (9). Lateral line a single short section curving posterodorsally from shoulder, ending beneath segmented dorsal-fin ray 6–10 (8/9), and consisting of 26–35 (31/35) pored scales. Olfactory capsule with two openings; anterior opening a short tube,
positioned about midway between posterior opening and edge of lip; posterior opening with slightly raised rim, positioned near anterodorsal rim of orbit (Figure 2). Cheek, upper edge of opercle (above horizontal through opercular spine) and body with small cycloid scales; predorsal scales extending anteriorly to parietal commissure (Figure 2). Teeth in outer row of premaxilla and dentary conical, recurved anteriorly, with one or two anterior teeth enlarged, caniniform and laterally displaced in large (greater than about 100 mm SL) specimens; teeth in outer row of premaxilla and dentary decreasing in size and becoming laterally compressed posteriorly, numbering 14–21; one to three inner rows of small conical teeth present anteriorly on premaxilla and dentary; vomer with a single row of about five small conical teeth arranged in a chevron; palatine edentate.

Live coloration (based on colour transparency of 101.8 mm SL paratype, MPM 32574, when freshly dead): body and upper part of head mottled brown; large (slightly larger than pupil) dark grey spot on upper part of operculum, broadly edged ventrally in pale yellow to white; irregular dark grey-brown stripe extending from behind eye to dark spot on operculum, edged narrowly along ventral edge with pale blue to white; lower part of head immediately below stripe abruptly pale bluish to greenish brown, becoming yellowish brown anteriorly; short dark grey-brown bar extending from posteroventral edge of eye (at about 5 o’clock position) toward lower (anterior) tip of preopercle, edged with pale blue or green to white; diffuse dusky brown stripe extending from anterior edge of eye to anterior part of upper lip; diffuse dusky brown stripe extending from posterodorsal edge of eye towards nape; small dark grey spot on lower part of operculum; lower part of head flecked with irregular pale blue to pale green markings; iris red, cream distally, with reddish brown to dark brown spots around perimeter; body mottling forming about 22 irregular dark bars; small dark grey spot on pectoral-fin base adjacent to third to sixth rays, broadly edged ventrally and dorsally with cream;
A new subgenus and species of Pseudochromidae

Figure 7 Collection localities for Congrogadus (Pilbaraichthys) winterbottomi. Black inset star indicates type locality (Middle Mangrove Island).

dorsal, anal and caudal fins yellowish to brownish hyaline, fin rays yellow or green to brown; dorsal and anal fins with basal row of reddish spots anteriorly, increasing to about six or seven rows posteriorly, these aligning to form oblique stripes, which converge on caudal fin; pectoral fin yellowish brown.

Preserved coloration: similar to live colour pattern; dark spot on operculum prominent, becoming dark grey-brown to black; dark bars and stripes extending from posterior, posterodorsal and posteroventral edges of eye prominent, becoming dark grey-brown to black; several dark grey-brown to black spots variably present on lower part of head and on breast; dark spot on pectoral base remaining, becoming dark grey-brown to black; dark mottling on body variable, ranging from indistinct in pale specimens to distinct in dark specimens, number of dark bars varying from about 20 to 27; dark spots on dorsal, anal and caudal fins usually distinct, ranging from grey-brown to black.

Comparisons

Congrogadus winterbottomi superficially resembles C. subducens in general coloration and body shape; we initially identified our material of C. winterbottomi as C. subducens. However, in addition to the characters noted above in the subgeneric relationships section, C. winterbottomi is readily distinguished from C. subducens in having a dorsal-fin spine (versus spine absent), segmented dorsal-fin rays 57–61 (versus 68–79; mistakenly stated as 68–74 by Winterbottom, 1986: 15), segmented anal-fin rays 46–50 (versus 57–66), and vertebrae 15–16 + 48–50 = 63–65 (versus 17–18 + 57–67 = 74–84). Moreover, the distinctive head coloration, particularly the pattern of dark lines radiating from the lower edge of the eye, readily distinguishes C.
winterbottomi from C. subducens and all other congrogadine species.

Habitat and distribution
Congrogadus winterbottomi has been collected only from muddy rock pools at Middle Mangrove Island (type locality) and Exmouth Gulf (Figure 7). Despite sampling in similar habitats, it was not collected farther offshore during the West Pilbara Island survey, nor in comprehensive collections made by the third author and associates farther to the south (Ningaloo Reef and Shark Bay) and north (Dampier Archipelago and the Kimberley coast). Narrow distributions such as this are not unusual for pseudochromids, with several confined to the northwestern Australian coast. For example, Assiculoides desmonotus Gill and Hutchins 1997 is known only from the north Kimberley coast (Gill and Hutchins, 1997; Hutchins, 1999).

The Exmouth Gulf and Middle Mangrove Island specimens of C. winterbottomi differ slightly in several meristic characters (Table 1). In particular, the Exmouth Gulf specimens have modally one more dorsal- and anal-fin ray, one more vertebra, and one fewer lower raker on the outer surface of the first gill arch, and a lower average number of pseudobranch filaments. However, these apparent differences may reflect the small sample sizes, and we therefore have chosen not to recognise them taxonomically.

Remarks
Congrogadus subducens was collected in two of the rotenone stations with C. winterbottomi, one specimen at Middle Mangrove Island in 1996, and two specimens at Burnside Island in 1995. An additional eight specimens of C. subducens were collected at the latter locality during the 1996 survey, but no further specimens of C. winterbottomi were taken.

Etyymology
The specific epithet is for our colleague and friend Rick Winterbottom, in recognition of his important contributions to the systematics and biogeography of congrogadines and other fishes and in appreciation of the support and encouragement he has given us.

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A new subgenus and species of Pseudochromidae

(Eds) Ontogeny and systematics of fishes. American Society of Ichthyologists and Herpetologists Special Publication 1.


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Abstract – The first collection of *Macrobrachium* from caves on Christmas Island, Indian Ocean is reported. Represented in the collection is the wide-ranging *M. lar* (Fabricius, 1798), and *M. microps* Holthuis, 1978, previously known from freshwater caves in the Southwest Pacific. The former is more typically an epigeal species and has previously been reported from surface waters on Christmas Island, while the latter appears to be an obligate hypogean species.

INTRODUCTION

The *Macrobrachium* fauna of Christmas Island previously consisted of two wide-ranging Indo-West Pacific species, viz. *M. lar* (Fabricius, 1798) and *M. rosenbergii* (De Man, 1879). The first record of the genus from the island was by De Man (1905) who recorded *M. lar* from a small freshwater pool above a waterfall. This material resulted from collections made by Dr R. Hanitsch of the Raffles Museum, Singapore. Gibson-Hill (1947) provided further details on Hanitsch’s collection site and the distribution of *M. lar* on Christmas Island, ‘occurs only in this small stream running into Panchoran Bay [now known as Waterfall], and in the water-storage tank which is supplied from it’. Calman (1909) also recorded *M. lar* from Hugh’s Dale and Sidney’s Dale on the west coast, based on material collected by Dr C. W. Andrews during 1897–1898 and 1908.

Gordon (1935) listed *M. rosenbergii* from Flying Fish Cove on the northwest side of the island and recorded further material of *M. lar*, including a record from Dolly Beach on the eastern side.

The present material results from collections made by Humphreys and Eberhard (1998) in caves on the north coast, one of the present authors (P.M.) in Daniel Roux Cave in 1996 and D. Powell at Waterfall in 1978. Included are the first cave records of the genus from Christmas Island and the first records of the obligate hypogean species, *M. microps* Holthuis, 1978. Apart from Henderson’s Spring and Waterfall, all of the collection sites are anchialine habitats – fresh groundwater systems overlying seawater with limited surface expression (W.F. Humphreys, personal communication). The only other anchialine system reported from Australia is in the vicinity of Cape Range and Barrow Island in northwestern Australia (Humphreys, 1993; Yager and Humphreys, 1996). Anchialine systems are noted both for their relict faunas, species richness (Sket, 1981, 1996) and their extraordinary vulnerability to even the slightest organic pollution (Iliffe et al., 1984; Notenboom et al., 1994).

In the following accounts all carapace lengths (CL) are measured from the orbital margin to the posterior carapace. Female specimens are non-ovigerous unless stated otherwise. Numbers enclosed in parentheses and with the prefix ‘WAM C’ refer to registered lots in the Crustacea collection, Department of Aquatic Zoology, Western Australian Museum. Field numbers used by Dr W.F. Humphreys, Department of Terrestrial Invertebrates, Western Australian Museum have the prefix ‘BES’. In the diagnoses the abbreviation ‘P2’ refers to the second pereiopods. The rostrum formula is given as the number of dorsal rostral teeth over the number of ventral rostral teeth. Line drawings were made with the aid of a camera lucida and stereo microscope.
SYSTEMATICS

*Macrobrachium lar* (Fabricius, 1798)

Figure 1

Restricted synonymy

*Palaemon lar* Fabricius, 1798: 402.


*Bithynis lar*: Bate, 1888: 789, plate 129, figure 1.

*Palaemon (Eupalaemon) lar* var.? De Man, 1905: 544, plate 18.

*Palaemon lar* var.: Calman, 1909: 706.


Material Examined

Australia: Christmas Island: Adult ♂, 32.8 mm CL, ovigerous ♀, 19.2 mm CL, Henderson’s Spring outflow, ca. 80 m above sea level, Karst Cl 64, from net filtering pump house outlet, 10°29'13"S, 105°40'40"E, W.F. Humphreys, R. Webb, 7 April 1998, BES 5861 (WAM C24439); adult ♀, 19.9 mm CL, Waterfall, at night on wet rock face, D. Powell, 17 October 1978 (WAM C12457); undeveloped ♂, 21.1 mm CL, Karst Cl 54, 10°25'23"S, 105°42'03"E, depth 0.2 m, W.F. Humphreys, 30 March 1998, BES 5777 (WAM C24440); 2 postlarvae ("dionyx" stage), 2.5, 2.6 mm CL, Karst Cl 54, 10°25'23"S, 105°42'03"E, brackish, 2 m, baited net, S.M. Eberhard, 17 April 1998, BES 5948 (WAM C24441); 1 postlarva ("dionyx" stage), 2.3 mm CL, Karst Cl 54, 10°25'23"S, 105°42'03"E, brackish, 3 m, baited net, S.M. Eberhard, 7 April 1998, BES 5952 (WAM C24442).

Diagnosis

Rostrum short in fully developed males, developmental range 0.5–0.7 CL; dorsal and ventral carinae well developed; dorsal carina sinuous or upturned, dentate along entire length, teeth tending to be more closely spaced at mid-length, 7–10 teeth, 1–2 completely postorbital; ventral carinae dentate, 2–4 teeth, first tooth located in proximal half or at about mid-length of ventral carina.

Ocular cornea large, well-pigmented, accessory pigment spot present. Inferior orbit moderately produced, obtuse, postantennular carapace margin evenly rounded. Bec ocellaire moderately developed. Epistome completely divided into two lobes, lobes strongly produced anterodorsally.

P2 of developed males isomorphic in setation and shape, unequal in length; long, merus of minor cheliped reaching distal end of scaphocerite; fingers with well developed gape; pollex elongate, not noticeably broadened basally, about equal in breadth to basal dactylus, strongly uncinate at tip, proximal cutting edge with dentate ridge ending in tooth, distinct gap then very large incisor tooth, distally entire; dactylus elongate, strongly uncinate at tip, proximal cutting edge with few low crenulations then very large incisor tooth well advanced of most distal tooth on pollex, distally entire; manus subcylindrical, much longer than dactylus; carpus of moderate length, less than half length of chela; merus slightly longer than carpus.

Thoracic sternite 4 with well-developed median process. Inter-uropodal sclerite with strongly-developed pre-anal carina.

Colour

As is typical of many species of the genus there is significant geographic and developmental colour variation. General body colour varies from light olive to dark brown or blue. In adults, the carapace...
Cave *Macrobrachium* from Christmas Island

is often marked with swirls of orange brown, blue grey and light olive grey. The dorsal abdomen is typically much darker than the lower pleurae and the condyles distinctively marked with light cream to orange.

The first chelipeds and ambulatory legs vary from olive to dark brown or blue. The second chelipeds are olive to dark brown, sometimes marbled with irregular brown, olive or blue-grey blotches. The fingers are dark reddish brown. The manus has an orange or light red blotch near the base of the dactylus.

**Habitat**

Although adults of the species are predominantly found in fresh waters, juveniles have been reported in the literature from estuaries, lowland fresh waters and inshore marine areas. The specimens from Karst Cl 54 are the first anchialine records of the species.

In northern Australia, the species is largely restricted to permanently-flowing, high gradient coastal streams. Adults show a preference for well oxygenated pools below riffles or waterfalls and shelter in poorly lit areas among tree roots, piles of large rocks or fallen timber.

**Distribution**


**Remarks**

This species has been extensively illustrated in the literature (e.g. Bate, 1888; Chace and Bruce, 1993; Holthuis, 1950; De Man, 1905). Among Indo-West Pacific species, fully developed males of *M. lar* are highly distinctive and are easily distinguished by the short, sinuous rostrum and long, robust second pereiopods with widely gaping fingers, each bearing a very large incisor tooth on the cutting edge. The P2 merus in adult specimens is also longer than the carpus. This character easily separates *M. lar* from the other large *Macrobrachium* recorded from the island, *M. rosenbergii*, which has the carpus clearly longer than the merus.

The postlarval specimens examined show general agreement with the description of the "dionyx" stage by Holthuis (1950) although all are somewhat damaged and poorly preserved. In particular the hepatic spine is in a submarginal branchiostegal position, the dactyli of the third to fifth pereiopods vary from feebly to distinctly biunguiculate and in one of the three specimens there is a clear supraorbital tubercle on each side of the carapace. The shape of the rostrum and arrangement of rostral teeth is also as figured by Holthuis (1950), with the posterior dorsal teeth more widely spaced than the anterior teeth. The rostral formula for the three specimens is 7-9/2-3.

The eggs of this species are small (0.9 mm maximum length) and numerous (up to 40 000 per brood; Kubota, 1972). Larval development is extended, with at least 11 planktonic stages and over 89 days to metamorphosis in seawater at 23–26.5°C (Atkinson, 1977).

*Macrobrachium microps* Holthuis, 1978

Figures 2–3

*Macrobrachium microps* Holthuis 1978: 210–214, figures 1, 2; Bruce and Iliffe 1993: 83–96, figures

**Figure 2** *Macrobrachium microps* Holthuis, 1978. A–C, small undeveloped $\delta$, 11.9 mm CL, WAM C24444: A, rostrum; B, right chela and carpus of P2; C, abdominal pleurae 3–6. D, adult $\Omega$, 23.8 mm CL, WAM C24443, anterior cephalothorax. Scale bar divisions (D) and solid scale bars (A–C), 1 mm.
1–6; Short and Marquet, 1998: 403 (key), 407–408, figure 4.

Material Examined
Australia: Christmas Island: Adult ♂, 23.8 mm CL, main Daniel Roux Cave (6CI-3), 10°26'26"S, 105°39'38"E, hand collected, 50 cm depth, P. Meek, 1996 (WAM C24443); undeveloped ♀, 11.9 mm CL, freshwater cave, Karst Cl 10, 10°30'48"S, 105°37'24"E, trapped, W.F. Humphreys, 2 April 1998 (WAM C24444).

Diagnosis
Rostrum short in fully developed males; dorsal and ventral carinae well developed (ventral carina typically slender); dorsal carina slightly sinuous, armed with 10–12 teeth; 4–5 completely postorbital; ventral carina with 3–5 teeth, first tooth located in proximal half or at about mid-length.

Ocular cornea reduced, well-pigmented. Inferior orbit poorly to moderately produced, obtuse, postantennular carapace margin evenly rounded. Epistome bilobed, lobes poorly developed, rounded, widely separated, strongly divergent anteriorly.

P2 of developed males fully dimorphic, short, minor cheliped reaching scaphocerite by carpus or more distal segments. Major cheliped without setal pubescence, chela with gape between fingers, manus moderately broadened, maximum breadth much greater than maximum merus breadth; carpus clearly shorter than chela; merus ca. equal in length to carpus or slightly shorter. Minor cheliped without setal pubescence, chela with well developed gape between fingers, manus moderately broadened, breadth clearly greater than maximum merus breadth, clearly shorter in length than dactylus; carpus clearly shorter than chela; merus slightly shorter than carpus.

Thoracic sternite 4 with median boss. Fourth and fifth abdominal pleurae posteroventrally acute (fourth pleura angular in small undeveloped male), inter-uropodal sclerite with elevated, setose, preanal carina.

Colour
The adult female from Daniel Roux Cave was rather uniformly pale cream in colour and lacked a distinct colour pattern. The cephalothorax was slightly tinged with olive and the dorsal abdomen tinged with yellow.

Habitat
Lower and upper Daniel Roux Cave consists of quaternary limestones (Spate and Webb 1998) which are tidal influenced (0–1.4 metres) (Faukland, 1999) although pools do remain at very low tides. Habitat is anchialine and there is a freshwater lens over salt water. Conductivity of the freshwater input (Gusher) has a mean value of 0.6–2 mS cm⁻¹ and subterranean water conductivity ranges from <1–25 mS cm⁻¹ (Faukland, 1999; Humphreys and Eberhard, 1989).
Cave *Macrobrachium* from Christmas Island

Freshwater Cave, which is on the opposite side of the island from Daniel Roux Cave, is also part of an anchialine system and opens from a marine terrace at an altitude of ca. 30 m. The fresh water within the cave is at sea level and is under strong tidal influence (W.F. Humphreys, personal communication).

**Distribution**

Previously recorded from freshwater caves in the Southwest Pacific: Danmin Cave, near Konogusgus, New Ireland (type locality); West Samoa; and Lifou Island, New Caledonia.

**Remarks**

The single adult female agrees closely with previously described specimens although the rostral formula (12/5) is slightly higher than given by Short and Marquet (1998) for the species (10-11/3-4). The dorsal series of rostral teeth is irregularly spaced near the mid-length in the present specimen whereas in previous specimens the rostral teeth are sub-equally spaced. The antennal and hepatic spines are well-developed, although the latter is broken off on the left side.

The species can easily be distinguished from congeners using the following combination of characters: fourth and fifth abdominal pleurae posteroventrally acute (fourth angular in small undeveloped male); ocular cornea reduced, but well pigmented; and an obtuse, evenly rounded inferior orbit.

The size of the ova in this species remains unknown. The presence of the species in freshwater caves on Christmas Island, quite a considerable distance from previous records in the Southwest Pacific, strongly suggests that *M. microps* has extended larval development and tolerance of seawater during the larval phase.

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Dr. Bill Humphreys (Western Australian Museum, Perth) provided most of the material reported and supplied useful habitat information. He also gave the details of a number of important published studies on anchialine cave systems. Tony Faukland, ACT Electricity and Water (Research), led the expedition into Lower Daniel Roux Cave.

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Descriptions of new Leptophlebiidae (Insecta: Ephemeroptera) from Australia. II. Kaninga, a new monotypic genus from south-western Australia

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Abstract – The genus Kaninga gen. nov. is established to accommodate a new leptophlebiid mayfly species from south-western Australia. Adults and nymphs of K. gioabbalitcha sp. nov. are described and figured. Identification keys are presented for both adults and nymphs of the leptophlebiid genera known to occur in south-western Australia.

The first record of the mayfly family Leptophlebiidae from south-western Australia was that of Ulmer (1908), who ascribed adult material to two south-eastern Australia species, Atalophlebia furcifera Eaton and Atalophlebia inconspicua Eaton. Although the material available to Ulmer has not been re-examined, these identifications are certainly incorrect. The two taxa are probably Neboissophlebia occidentalis Dean 1988 and an undescribed species of Nousia, respectively. An identification key to nymphs of both described and undescribed genera of Australian Leptophlebiidae was published recently (Dean, 1999). Seven genera, two of which were undescribed, and nine species were recognised from south-western Australia. While additional taxa can be expected, the fauna clearly is not diverse.

This paper is one in a series describing new Australian leptophlebiid taxa (Dean, 1997; Dean et al., 1999). A new monotypic genus is established and diagnosed to accommodate a new species from south-western Australia. Additional genera will be described as nymphs are associated with adults and sufficient adult material becomes available. Examined material was preserved in alcohol, with parts of some specimens mounted on microscope slides. Material is lodged in the entomology collections of the Museum of Victoria (NMV) and the Western Australian Museum (WAM).

Kaninga gen. nov.

Type Species

Kaninga gioabbalitcha sp. nov.

Diagnostic Features

Imago

Forewing length-width ratio 2.9 to 3.0; membrane hyaline, without pigment spots (Figure 1); costal and subcostal cells in apical third of wing translucent, whitish; 5–6 weakly developed costal crossveins basal to the bulla, about 14 distal to the bulla; MA forked at 0.41–0.43 wing length; MP attached by crossvein to MP at 0.17–0.18 wing length; base of ICu, either linked to CuA–CuP crossvein or, more usually, attached by cross vein to CuA; ICu and ICu diverging as wing margin approached. Hindwing about 0.22 length of forewing; costal margin with shallow concavity just beyond midlength, costal space relatively broad in basal half of wing and narrow distally (Figure 2); vein Sc joining costal margin at a little less than 0.9 wing length; hindwing with about 10 costal crossveins and 6–7 subcostal crossveins. All legs with tarsal claws similar, each with an apical hook and opposing ventral flange (Figure 5). Forelegs of male with ratios of segment lengths 0.84–0.86; 1.00 (3.0 mm); 0.05: 0.32–0.33: 0.31–0.32: 0.25: 0.11–0.12. Male genitalia with claspers three-segmented, basal segment narrowing at about mid length (Figure 6). Penis lobes (Figures 7–10) relatively robust, separated almost to base; each lobe with a broad ventral projection at about ¾ length; gonopores apical. Female ninth sternum with apical margin deeply excavated (Figure 11).

Subimago

Wings uniformly yellowish to pale brown.

Mature nymph

Head prognathous, antennae 1½ – 2 x width of head. Mouthparts as in Figures 18–23. Clypeus with lateral margins slightly diverging anteriorly. Labrum a little broader than clypeus; width about 2.0x length along median line; broadest a little beyond midlength; anterior margin shallowly concave; frontal fringe a narrow band 3–4 setae deep, sub-apical fringe a single row of setae a little
posterior to frontal fringe. Mandible with outer margin bearing tuft of long setae at midlength; setae absent between tuft and incisors, but a series of shorter and finer setae basal to tuft; incisors slender, three apical points and usually three sub-apical spines; prostheca strongly developed. Maxilla with sub-apical row of about 25 pectinate setae; palp moderately short, terminal segment about 2/3 length of middle segment; middle segment bearing simple setae only. Labium with glossae turned under ventrally, not lying in same plane as paraglossae; palp 3-segmented, terminal segment almost as long as middle segment. Legs relatively robust, banded (Figure 13); femur broad, outer margin with row of stout spine-like setae, upper surface with numerous short spine-like setae; all
Figures 6-11  *Kaninga guabbalitdia* sp. nov. Male imago: 6, genitalia, ventral; 7, penes lobes, dorsal; 8, left penes lobe, lateral; 9, penes lobes, apical; 10, penes lobes, ventral (slide preparation). Female imago: 11, sternum nine.

segments with sparse fringe of fine setae along outer margin; tarsal claws (Figure 14) with about 20 small ventral denticles. Abdominal segments with postero-lateral spines on segments 4-9; posterior margins of abdominal terga with continuous row of stout spines (Figure 15), longer and shorter spines interspersed. Gills (Figure 16) present on abdominal segments 1 to 7, each gill with both lamellae broadly lanceolate, narrowing at about 2/3 length, with lateral tracheae strongly developed. Caudal filaments (Figure 17) with apical whorl of stout spines on each segment, and a series of 4 or 5 fine setae between each stout spine.

Remarks

The genus has been included previously in identification keys under the designation 'Genus Q' (Dean and Suter, 1996; Dean, 1999). *Kaninga* can be
Kaninga guabkalitcha sp. nov. Nymph: 12, habitus; 13, foreleg; 14, foretarsal claw; 15, spines on posterior margin of abdominal tergum five; 16, gill from abdominal segment four; 17, terminal filament, midlength.

distinguished from all other leptophlebiid genera by the following combination of characters. Imago: (1) forewing with ICu, and ICu', diverging as wing margin approached; (2) forewing approximately 4.5x length of hindwing; (3) hindwing with anterior margin broadly rounded. Sc joining wing margin at about 0.9 wing length; (4) tarsal claws similar; (5) male genitalia with penes lobes separated almost to base; each lobe with a broad ventral projection at about ¾ length; (6) ninth sternum of female with apical margin deeply cleft. Nymph: (1) labrum slightly broader than clypeus, width about 2.0x
New genus of mayfly from south-western Australia

Figures 18-23 Kaninga gwabbiitricia sp. nov. Nymph: 18, labrum; 19, left mandible; 20, incisors, right mandible; 21, right maxilla, ventral; 22, labium, dorsal (left of midline) and ventral (right of midline); 23, terminal segment of labial palp, dorsal.

length along median line; (2) maxilla with sub-apical row of about 25 pectinate setae; (3) labium with glossae turned under ventrally, not lying in same plane as paraglossae; (4) tarsal claws with about 20 small ventral denticles; (5) posterior margins of abdominal terga with continuous row of stout spines, longer and shorter spines interspersed; (6) abdominal gills broadly lanceolate, narrowing at about 2/3 length.

Although Kaninga appears close to Bibulmena, also
from south-western Australia, many of the shared characters (e.g. wing venation, form of the tarsal claws in the imago, shape of sternum nine in the female) are plesiomorphies and therefore not in themselves indicative of a close relationship. Phylogenetic relationships within the Australian Leptophlebiidae have yet to be investigated, and until characters of all genera have been properly assessed the relationship of *Kaninga* to other genera will remain problematic. Autapomorphies which characterise *Kaninga* include the development of large ventral projections on the penes lobes of the adult and the reduction in size of the ventral processes on the tarsal claws of the nymph.

### Etymology

The generic name is based on *kan-ing*, a Nyoongar aboriginal word meaning the south-west (Bindon & Chadwick, 1992), in recognition of the apparent restriction of the genus to south-western Australia.

*Kaninga gubballitcha* sp. nov.

*Figures 1–23*

### Material Examined

**Holotype**

δ imago, Carey Brook, Staircase Road, Western Australia, Australia, 34°24'S, 115°51'E, 15 December 1989, I. Crowns (NMV).

**Paratypes**

2 male imagos, same locality and collection data (NMV) (wings, genitalia and legs of one paratype mounted on microscope slides).

### Other Material Examined

**Australia:** Western Australia. 1 reared male subimago, 1 reared female subimago, type locality, 2 December 1988, I. Crowns; 1 female imago, 2 female subimagos, 16 nymphs, type locality, 15 December 1989, I. Crowns (NMV, WAM); 7 nymphs, Carey Brook, 20km west of Pemberton, 26 November 1978, A. Neboiss; 1 nymphp, Carey Brook, Vasse Highway, approx. 16km west of Pemberton, 5 September 1980, A. Wells; 1 nymphp, Donnelly River, Sandy Hill Rd, 34°20'S, 115°50'E, 2 Nov 1995, MRHI (Monitoring River Health Initiative); 1 nymphp, Beedelup Brook, 34°25'S, 115°52'E, 28 January 1995, MRHI; 1 nymphp, Fish Creek, O'Sullivan 12 Road, 34°40'S, 116°22'E, 11 October 1994, MRHI.

### Description

**Imago**

Length of male: body 9.3–10.1 mm, forewing 10.2–10.3 mm; Length of female: body 12.3 mm, forewing 12.8 mm. Antennae with pedicel and scape reddish-brown, flagellum brownish/yellow. Ocelli white, black at base; lateral ocelli about 2x diameter of medial ocellus. Upper lobes of male eyes pale brown-orange, in contact dorsally; lower lobes grey-black. Pronotum yellow, carinae and lateral margins dark brown, some brown pigmentation on surface between carinae. Meso- and metanotum golden brown, thoracic pleura golden with localised patches of dark brown. Legs without banding; forefemur medium brown, middle and hind femora slightly paler and with less uniform brown pigmentation; remaining segments of all legs yellow. Abdominal terga with pattern of contrasting pale yellow (sometimes with a reddish tinge) and dark brown (Figures 3, 4); abdominal sterna uniformly washed with pale red. Terminal filaments pale, medial filament strongly developed. Penes lobes (Figures 8–10) each with a broad ventral projection at about 2/3 length.

**Subimago**

Wings uniformly pale yellowish to brown; abdominal markings similar to imago but without reddish hue.

**Mature nymph**

Robust, general colour medium brown/yellow. Dorsum of head predominantly medium brown, paler yellow between eyes, dark brown almost black in region of ocelli (Figure 12). Antennae pale yellow. Labrum width about 2.0x length along median line; anterior margin shallowly concave; frontal fringe a narrow band of setae, sub-apical fringe a single row of setae. Legs pale yellow with medium brown banding (Figure 13). Abdominal terga contrasting dark brown and yellow; segments 7 and 8 paler than remaining segments (Figure 12); abdominal sterna pale yellow. Gill lamellae white, tracheae dark brown.

### Distribution

The species appears to be restricted in distribution to small- and medium-sized forest streams in south-western Australia.

### Etymology

The species name is derived from *gubballitch*, the Nyoongar word for handsome, and refers to the striking appearance of the adult.

### Keys to genera of Leptophlebiidae from south-western Australia

Seven leptophlebiid mayfly genera are now known from south-western Australia. Of the two undescribed genera previously recognised (Dean, 1999), 'Genus Q' is described in the present work.
New genus of mayfly from south-western Australia

Examination of associated adults of ‘Genus S sp.AVI’ indicates that species of the second genus can be accommodated in *Loamaggalangta*.

**Imagos**

1. Tarsal claws dissimilar, one slender with an apical hook, the other swollen, pad-like (Dean, 1988, figure 9) .......................... *Neboissophlebia*
   - Tarsal claws similar, each with an apical hook and opposing ventral flange (present study, figure 5; Dean, 1987, figure 30) .................. 2
2. Hindwing with conspicuous projection on costal margin (Dean, 1987, figure 2) ............... *Nyungara*
   - Hindwing without projection, costal margin gently curved (present study, figure 2: Dean, 1987, figure 24) ................................ 3
3. Forewing with ICu, and ICu, strongly diverging as wing margin approached (present study, figure 1; Dean, 1987, figure 23) .................. 4
   - Forewing with ICu, and ICu, weakly diverging or parallel as wing margin approached (Dean et al., 1999, figure 1; Ulmer, 1908 figure 27) ............. 6
4. Forewing with 20 or fewer costal crossveins (present study, figure 1) .......................... *Kaninga*
   - Forewing with 25 or more costal crossveins (Dean, 1987, figure 23) .................. 5
5. Forewing with costal crossveins anastomosed in apical ¼ of wing (Dean, 1987, figure 23) .......... *Bibulmena*
   - Forewing with costal crossveins not anastomosed in apical ¼ of wing (Suter, 1986, figures 1a, 3a) ..................................... *Atalopthebia*

**Nymphs**

1. Abdominal gills with three apical filaments (Dean, 1999, figure 43) .......................... *Atalopthebia*
   - Abdominal gills either lanceolate or narrowing to single apical filament (present study, figure 16; Dean, 1987, figures 15, 35) ............ 2
2. Tarsal claws smooth (Dean, 1988, figure 16) or with very small ventral denticles (present study, figure 14) ........................................ 3
   - Tarsal claws with prominent ventral teeth (Dean, 1987, figure 14) .................. 6
3. Tarsal claws with small ventral denticles (present study, figure 14) .......................... *Kaninga*
   - Tarsal claws smooth (Dean, 1987, figure 34; Dean, 1988, figure 34) .................. 4
4. Labrum relatively broad, width 2.3 to 2.5 x length along median line (Dean, 1999, figure 122); gills very narrow, linear, without lateral tracheae (Dean, 1999, figure 121) .......................................................... *Neboissophlebia*
   - Labrum less broad, width 1.7 to 1.9 x length along median line (Dean, 1987, figure 37; Dean, 1999, figures 73, 230, 232); gills variable, narrow, moderately or broadly lanceolate (Dean, 1999, figures 76, 231, 233) .......................... 5
5. Gills broad, lateral tracheae strongly developed; inner margin of each lamella convoluted to form small recess near base of terminal filament (Dean, 1999, figure 76) ..... *Bibulmena*
   - Gills narrow to moderately broad, lateral tracheae varying from almost absent to moderately developed, inner margins of lamellae never with recess (Dean, 1999, figures 231, 233) ........................................... *Loamaggalangta*
   - Labrum with sparse but well-defined sub-apical setal fringe (Dean, 1999, figure 129) ..... *Nousia*
   - Labrum without sub-apical setal fringe (Dean, 1999, figures 170, 171) .......................... *Nyungara*

**ACKNOWLEDGEMENTS**

Dr Ivor Growns collected the material on which the descriptions are based, and he is thanked for making the specimens available. Dr Ken Walker, Curator of Entomology, Museum Victoria, is thanked for making available material held in the collections of the museum. Part of the work on immatures has been funded by the Land and Water Resources Research and Development Corporation as an MKHI R&D project. Dr Alice Wells and Dr Phil Suter are thanked for constructive comments on the original manuscript.

**REFERENCES**


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A new species of *Austrocypraea* (Gastropoda: Cypraeidae) from the Late Pliocene of the Eucla Basin, southern Australia

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Abstract – A new species of fossil cowrie, *Austrocypraea amae* sp. nov., hitherto misidentified, is described from the Roe Calcarenite of the Eucla Basin. The new species is intermediate in morphology between the Miocene *A. contusa* (McCoy, 1877) and the extant *A. reevei* (Sowerby, 1832). It provides the first confirmation from the Pliocene for this endemic southern Australian genus.

**INTRODUCTION**

In her pioneering contribution on the malacofauna of the Roe Calcarenite of the Eucla Basin, Ludbrook (1978), from limited material, recorded the present species as *Cypraea (Austrocypraea) reevei* Sowerby, whilst noting some differences from the typical form of that species, the sole living representative of the genus.

Re-examination of the Ludbrook material, together with a wider range of additional specimens, has led the present authors to conclude that the Roe *Austrocypraea* differs consistently from all others of the genus sufficiently to justify its recognition as a new species. *Austrocypraea amae* sp. nov. presents an intermediate morphology and age between the Miocene *A. contusa* (McCoy) and the extant *A. reevei* (Sowerby).


**SYSTEMATICS**

Family Cypraeidae Rafinesque, 1815 (as Cypridia)

Genus *Austrocypraea* Cossmann, 1903

Type Species

*Cypraea (Luponia) contusa* McCoy, 1877.

*Austrocypraea amae* sp. nov.

Figures 1, A-L, 2, A-J

1978 *Cypraea (Austrocypraea) reevei* Sowerby; Ludbrook: 130, plate 13, figures 17, 18.

**Material Examined**

**Holotype**

WAM 69.495, from Roe Plains, Madura district, Western Australia; spoil from foundation holes, Hampton Microwave Repeater Tower (lat. 31°57'57"S, long. 127°34'45"E), collected T.A. Darragh, M. Archer and G.W. Kendrick, 5 March 1969. Roe Calcarenite, Late Pliocene.

**Paratypes**

HMB 102445-50, from Roe Plains. Total of six specimens. NMV P303505/6, excavation 1.5 km N of type locality (NMV locality PL 3167). Two specimens. WAM 80.67 a, b, c, g, excavation 1.5 km N of type locality; basal 0.4 m carbonate sand. 80.145a-j, excavation 0.5 km N of type locality, spoil heaps on floor of pit. Fourteen specimens.

**Other material**

WAM 62.32a-b, 65.685, 69.496, 69.517, 69.550, 69.575, 70.18, 70.1819, 71.321, 71.331, 80.67d-f, h, 80.108, 82.2444. Total of 18 specimens. Collection of D. Fehse, unnumbered, total of 35 specimens.

All of the study material was collected from the Roe Calcarenite of the Eucla Basin, in Western Australia.

**Diagnosis**

Medium-sized, robust, somewhat variable *Austrocypraea*, ovate-subpyriform, occasionally subcylindrical, with spaced, weak to strong apertural dentition; columnellar teeth 14-22 (mean 16.8), labial teeth 17-32 (mean 22.8), latter always exceeding former; maximum globosity at posterior third; apex just visible or depressed and overlain by callus.

Diffsers from *A. reevei* in fewer, stronger, more spaced apertural teeth, more concealed apex, globosity greatest at posterior third and smaller...
size; from *A. contusa*, differs in more discrepant dentition, shorter anterior extremity, reduced globosity and malleation, more concealed apex and greater size.

**Description**

Medium size for genus, robust, somewhat variable, typically ovate-subpyriform, occasionally subcylindrical; length exceeds width and height;
A new Late Pliocene *Austrocypraea*

Table 1

<table>
<thead>
<tr>
<th>Specimens (catalogue numbers)</th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>Columellar teeth</th>
<th>Labial teeth</th>
</tr>
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<tr>
<td>WAM 69.495 holotype</td>
<td>38.9</td>
<td>26.7</td>
<td>22.3</td>
<td>21</td>
<td>32</td>
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<tr>
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<td>23</td>
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<tr>
<td>WAM 80.67a paratype</td>
<td>30.9</td>
<td>23.4</td>
<td>19.7</td>
<td>17</td>
<td>30</td>
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<tr>
<td>WAM 80.67b paratype</td>
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<td>20.3</td>
<td>18.1</td>
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<td>23</td>
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<tr>
<td>WAM 80.67c paratype</td>
<td>38.3</td>
<td>28.2</td>
<td>23.3</td>
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<td>17</td>
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<tr>
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<td>16.8</td>
<td>16</td>
<td>25</td>
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<td>20.7</td>
<td>17.3</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
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<td>18.9</td>
<td>16.0</td>
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<td>18</td>
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<td>WAM 80.145f paratype</td>
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<tr>
<td>WAM 80.145g paratype</td>
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<td>17.1</td>
<td>14.6</td>
<td>15</td>
<td>20</td>
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<tr>
<td>WAM 80.145h paratype</td>
<td>22.5</td>
<td>16.9</td>
<td>13.9</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>HMB 102445 paratype</td>
<td>27.3</td>
<td>18.8</td>
<td>16.0</td>
<td>16</td>
<td>23</td>
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<tr>
<td>HMB 102446 paratype</td>
<td>29.5</td>
<td>20.9</td>
<td>17.0</td>
<td>17</td>
<td>23</td>
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<tr>
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<td>15</td>
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<td>15.5</td>
<td>16</td>
<td>20</td>
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<td>HMB 102449 paratype</td>
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<td>19.1</td>
<td>15.7</td>
<td>18</td>
<td>24</td>
</tr>
</tbody>
</table>

Dimensions

Length refers to the greatest anterior/posterior measurement; width to the greatest lateral (left-right) measurement with the shell at rest on the base; height refers to the maximum globosity from the base through to the dorsal extremity. Counts of columellar teeth exclude the strong internal rib bordering the anterior canal. Denticles at the posterior end of the labial teeth have been counted as full teeth.

Etymology

The name of the species honours Mrs Elizabeth Ama Fehse.

REMARKS ON SHELL MORPHOLOGY

As *Cypraea (Austrocypraea) reevei* Sowerby, the present species was recorded from the Roe Calcarenite and described fully by Ludbrook (1978). The redescription herein, based on the previous and additional material, adds little. Ludbrook remarked on differences between specimen WAM 69.495 (holotype, figure 1, A-C) and "more typical C. (A.) reevei" (ibid., p. 130). She also noted the relationship of Sowerby's species to "C. (A.) contusa McCoy" from "Balcombe Bay" (= Mornington, Fyansford Formation, Balcombian), which is recorded in southeastern Australia from the Janjukan (Late Oligocene) to Bairnsdalian (late Middle Miocene) (Darragh, 1985; Li *et al.*, 1999).
Figure 2  A–J, *Aistrocypreea amae* sp. nov., Roe Plains, Western Australia (Roe Calcarenite, Late Pliocene). A–E, HMB 102445 (paratype). F–J, HMB 102446 (paratype). K–O *Aistrocypreea reevi* (Sowerby, 1832). Recent, Western Australia. DFB Collection, no. 2212 A15141514 (1188). Two apertural view of each specimen positioned to show labial and columellar dentition. All x 1.8.
The new species from the Roe Calcarenite presents a distinctive combination of shell characters that distinguish it from both *A. contusa* and *A. reevei*, consistent with a somewhat intermediate, probably transitional morphology connecting the two.

Notable intra-specific variation in shell characters is a feature of the temperate-water Cypraeidae of southern Australia, including *Austrocypraea reevei*, as has been remarked on by Wilson (1993: 172-198). In these groups, variable shell morphologies (and colours) appear to be a consequence of prolonged, direct larval development, associated with localised, favourable habitats and maintained by potentially high levels of planktonic predation. This contrasts with the generally prevailing planktotrophic larval development of the tropical cypraeids.

Wilson (1985: 276) reported that female *Austrocypraea reevei* brood the egg mass, which is connecting the two.

Table 2 Comparison of shell characters for *Austrocypraea contusa* (McCoy, 1877), *A. amae* sp. nov. and *A. reevei* (Sowerby, 1832).

<table>
<thead>
<tr>
<th>Characters</th>
<th>Species</th>
<th>A. contusa (Figure 1, M-Q)</th>
<th>A. amae sp. nov. (Figure 1, A-L)</th>
<th>A. reevei (Figure 1, R-W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maximum length</td>
<td>33.0</td>
<td>38.9</td>
<td>43.7</td>
<td></td>
</tr>
<tr>
<td>2. Shape</td>
<td>ovate-yriform, anteriorly extended; dorsal dome at ca posterior third</td>
<td>ovate-sub-yriform, occ. subcyllindrical; dorsal dome at ca posterior third</td>
<td>ovate-sub-yriform, occ. subcyllindrical; dorsal dome near middle</td>
<td></td>
</tr>
<tr>
<td>3. Sculpture</td>
<td>intensely malleate, base usually smooth</td>
<td>moderately to weakly malleate, mainly posteriorly; base smooth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Apex</td>
<td>visible, small</td>
<td>very small, often sunken or overlain by callus</td>
<td>visible, small, occ. slightly elevated</td>
<td></td>
</tr>
<tr>
<td>5. Columellar teeth</td>
<td>strong, spaced; 13-23 (mean 17.5)</td>
<td>usually strong, spaced; 14-22 (mean 16.8)</td>
<td>fine, close 21-30 (mean 25.3)</td>
<td></td>
</tr>
<tr>
<td>6. Labial teeth</td>
<td>strong, spaced, usually exceeding columellar teeth; 18-26 (mean 20.0)</td>
<td>usually strong, spaced, always exceeding columellar teeth; 17-32 (mean 22.8)</td>
<td>fine, close, always exceeding columellar teeth; 25-43 (mean 32.3)</td>
<td></td>
</tr>
</tbody>
</table>

A pink suffusion around the anterior and posterior (including apical) extremities is a feature of *A. reevei* and is occasionally visible in ordinary light on specimens of *A. contusa* (e.g., WAM G1509). A comparable faint, dark tinting at the extremities of specimens of *A. amae* may be seen under both ordinary (e.g., holotype) and UV light, evidently a persistence of the same character.

From this *mélange* of characters, we conclude that the three taxa (*contusa, amae* and *reevei*) represent a single evolutionary lineage, located during the Oligo-Miocene in southeastern Australia and subsequently (Pliocene-Recent) confined to southwestern Australia.

**DISCUSSION**

Kay (1996), apparently following Schilder (1935) and Schilder and Schilder (1971), incorrectly included *Austrocypraea* among the extinct genera of the Cypraeidae, assigning to it a time-range of Early Eocene to Late Miocene. The older part of this range appears to be derived from the Schilders' (ibid.) inclusion of *Cypraea ovulatella* Tate in *Austrocypraea*. *C. ovulatella* is a triviid and more credibly located in the genus *Willunga* Powell; it is more resemble *reevei* except that in the position of the dorsal dome and also in the number, size and spacing of the apertural teeth it lies closer to *contusa* (Figure 3). However, in *contusa* the labial teeth usually exceed in number the columellar teeth, within a range of -1 (WAM G1508) to +6 (ten specimens); with *A. amae* (70 specimens) and *A. reevei* (30 specimens), the labial teeth for both species always exceed the columellar teeth by a margin of +1 to +13. The apex is less prominent in *A. amae* than in either of the other two.
common in the Late Eocene of southern Australia and may persist into the Early Oligocene (Darragh, 1985). The time range of *Austrocypraea* on present knowledge is Janjukian (Late Oligocene) to Recent (ibid.). The present species provides the first authenticated record of the genus from the Pliocene, intermediate in age and morphology between the Miocene *A. contusa* and the extant *A. reevei*. Eight nominal species of *Austrocypraea* are on record from the Oligo-Miocene of southeastern Australia (Darragh, 1970 and references) but most of these, the exception being *A. contusa*, evidently represent extinct lineages.

The Roe Calcarenite (Lowry, 1970) is a thin (up to 7.5 m thick, usually much less), richly fossiliferous, bioclastic calcarenite, forming most of the surface of the Roe Plains along the onshore southern Eucla Basin. It overlies unconformably an erosion surface of Wilson Bluff (Eocene) and Abrakurrie (Oligo-Miocene) Limestones (Li et al., 1996). The Roe substratum was of fine carbonate sand with extensive seagrass development in shallow (to ca 10 m), well-circulated water along an open coast. Evidence for a Late Pliocene age is presented by Kendrick et al. (1991).

*A. amae* is common in the Roe Calcarenite and probably, like its modern equivalent *A. reevei*, was associated with hard substrates. These are not readily identifiable within the formation but were probably present along the eroding face of the Hampton Scarp, which formed the shoreline for much of the Late Pliocene Roe transgression.

No confirmed fossil record now stands for *A. reevei*. Despite extensive searching, no specimen has been recognised in the rich and well preserved assemblages from the Ascot Formation (Late Pliocene – Early Pleistocene) and Tamala Limestone (Middle – Late Pleistocene) of the Perth Basin (Kendrick et al., 1991). The Eucla Basin and Roe Calcarenite lie within the modern geographical range of *A. reevei*, which in WAM records extends from the Yorke Peninsula of central South Australia (longitude 137°E) to Kalbarri, Western Australia (latitude 28°S); anecdotal evidence, unconfirmed, would extend that range northward to about latitude 26°S.


**ACKNOWLEDGEMENTS**

D.F. expresses appreciation to Dr F. Lorenz junior for encouragement and helpful advice; Dr Piero Garonetti assisted in obtaining specimens for study. Mr W. Rumball kindly provided comparative material from the Miocene of the Murray Basin, South Australia. We thank Dr K.J. McNamara and Mrs S.M. Slack-Smith for access to collections and research facilities of the Western Australian...
A new Late Pliocene *Austrocypraea*

Museum and Ms K. Brimmell for photography; Mr H. Morrison kindly provided distribution data and assisted with literature.

REFERENCES


*Manuscript received 18 August 1999; accepted 13 March 2000.*
Australacarus (Acari: Halacaridae) from northern Australia, with the
description of three new species

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Australian Institute of Marine Science, P.M.B. 3, Townsville MC, Queensland 4810, Australia
e-mail j.otto@aims.gov.au

Abstract - The Great Barrier Reef and Coral Sea are inhabited by at least four
species of Australacarus Bartsch, namely A. pustulatus Bartsch and three new
species that are described here, A. longipalpus sp. nov., A. mesaktanus sp. nov.
and A. zagorskisae sp. nov. Australacarus pustulatus is also recorded from the
northwestern Australian Montebello Islands. Its larva, the first one known for
Australacarus, is described and compared with that of other halacarid taxa. A
key to Australacarus species is presented and Australacrini subfam. nov. is
proposed to accommodate Australacarus and Colobocerasides Viets.

INTRODUCTION

Halacaridae, 0.15-2 mm long aquatic mites that
occur in marine as well as freshwater habitats, have
reached astonishing diversity. Approximately 1000
species have been described but many more are
likely to exist. The present paper is part of a series
of publications dealing with the halacarids found
during a three year survey of the Great Barrier Reef
and Coral Sea. Among the species collected are four
Australacarus species, three of these new to science.

Two species of Australacarus were previously
known: A. inexpectatus Bartsch, 1987, from the
Chilean Magellan Strait, and A. pustulatus Bartsch,
1993, from Rottnest Island in southwestern
Australia. In contrast to most other halacarid genera
the cuticle of Australacarus species is mostly
membranous rather than sclerotised and the
rostrum is sharply pointed rather than blunt. Their
body is conspicuously elongate and filled with dark
brown matter and the legs are attached at the
extreme anterior and posterior ends, giving the
whole animal a rather sausage-like appearance.
Bartsch (1987, 1993) speculated that at least some of
these characters may be correlated with a suspected
parasitic mode of life. However, feeding has not
been observed and a predatory or even algivorous
lifestyle cannot be ruled out.

MATERIALS AND METHODS

All mites were extracted from sediment samples
by vigorously stirring the sediment in a bowl of
water and decanting the supernatant through a 100
μm sieve. All specimens were cleared in lactic acid
and mounted in PVA. Drawings were made from
compressed slide-mounted specimens. Specimens
with a QMS accession number are deposited in the
Queensland Museum (QM), at the branch Museum of
Tropical Queensland in Townsville. Abbreviations for other repositories are: ANIC,
Australian National Insect Collection; WAM,
Western Australian Museum, Perth; ZMH,
Zoologisches Institut und Zoologisches Museum
der Universität Hamburg.

Abbreviations used in text and figures: AD,
anterior dorsal plate; AE, anterior epimeral plate; d-
pas, doubled parambulacral seta(e); ds-3, ds-5, third
and fifth pair of dorsal setae, respectively, counted
from anterior; GA, genitoanal plate; gb,
gnathosomal base; OC, ocular plate; pas,
parambulacral seta(e); PD, posterior dorsal plate;
PE, posterior epimeral plate; pgs, perigenital seta(e);
P-1, P-2, P-3, first, second and third palp segments,
respectively, counted from base of palp; sgs,
subgenital seta(e); ro, rostrum; I-IV, leg I to leg IV;
ω, solenidion on leg tarsi I and II.

SYSTEMATICS

Australacrini subfam. nov.

Type Genus

Diagnosis
Idiosoma with two pairs of OC (Figure 1A). Six
pairs of dorsal idiosomal setae, the anterior-most on
the AD, the posterior-most on anal cone; remaining
four pairs either all in membranous cuticle, or three
pairs in membranous cuticle and one on PD. 2–4
pairs of platelets ventrally between AE and GA
(Figure 1C). Female GA usually with 2–3 pairs of
pgs, but no sgs. Rostrum stylet-shaped (Figure 2E);
two pairs of maxillary setae, one inserted about half
way along gnathosomal base, the other immediately
posterior to rostrum (Figure 2F). Palps separated by a distance that is not greater than the width of one proximal palp segment; with three or four segments. P-2 with one seta, apical palp segment with three basal setae. In species with four palp segments P-3 without a seta. Pharyngeal plate wider than half the width of gnathosomal base.

Remarks

Australacarinae subfam. nov is here proposed to accommodate Australacarus Bartsch, 1987, and Colobocerasides Viets, 1950 (see Bartsch, 1998a). The latter genus currently consists of two species, C. koehleri (Trouessart, 1896) from the northeastern Atlantic (gulf of Gascogne, 1410 m depth), and C. auster Bartsch, 1998, from the Western Antarctic (61°18.7'-61°17.4'S, 56°33.3'-56°30.5'W, 460-480 m depth).

Both genera are similar in several conspicuous and, for halacarids, unusual characters, most importantly two pairs of CXZ, a stylet-shaped rostrum, a series of ventral plates in the membranous cuticle between AE and GA, and a large pharyngeal plate. Other similarities, not quite as conspicuous but nevertheless rare in halacarids, include a single seta on basifemur III and IV and an unusually long solenidion on tarsus I. As it is unlikely that all these characters evolved convergently, a close relationship of Australacarus and Colobocerasides seems extremely likely. The Halacarinae to which they have previously been assigned (Bartsch, 1987) is a heterogeneous group which is not defined by any characters that are likely to be synapomorphic. Its function has mostly been to accommodate those genera that cannot be assigned to other better defined subfamilies and this has resulted in a rather unnatural assemblage. This problem needs eventually to be addressed comprehensively and the Halacarinae, as well as other halacarid subfamilies, needs to be redefined; however, this would involve a thorough cladistic analysis that is beyond the scope of the current project. Meanwhile, the reassignment of genera such as Australacarus and Colobocerasides, which are clearly not closely related to Halacarus, to better defined subfamilies appears a small though beneficial step towards achieving a more natural system of halacarid subfamily classification.

Genus Australacarus Bartsch


Remarks

Australacarus can be distinguished from Colobocerasides by the morphology of PD and PE. In Australacarus the PD is shorter than the AD and lacks setae, and the entire PE lies in the posterior 1/3 of the idiosoma. In Colobocerasides the PD is longer than the AD and has a pair of setae anteriorly, and the PE extends well into the anterior half of the idiosoma. Australacarus is known only from the southern hemisphere.

Australacarus longipalpus sp. nov.

Material Examined

Holotype

♀, QMS105551, ca. 17°25'S 151°40'E, Coral Sea, Lihou Reef, 22 July 1998, D. Fenner, sand at 7 m.

Paratypes


Description

Female

Holotype idiosoma 444 μm long, other specimen distorted. Membranous cuticle covered with numerous papillae (Figure 2C, D). AD, PE and AE finely punctate (Figure 1A-C). Posterior margin of AD convex; pair of gland pores in posterior half (Figure 1B), slightly anterior to pair of setae. Anterior OC (Figures 1A, 2A) more elongate than posterior OC (Figures 1A, 2B) and lacking pore, with series of fine canaliculi. In one specimen OC with large subsurface scar similar to that indicated by dotted line in Figure 2C, D for male, in other specimen no such scar seen. Posterior OC with pore and few scattered canaliculi. PD ca. twice as wide as long and distinctly wider than 1/2 the width of elongate, sausage-like, filled with a dark brown substance; four pairs of minute dorsal setae in membranous cuticle (Figure 1A); pair of setae ds-3 further apart than any other pairs of dorsal idiosomal setae. PE and AE at the extreme anterior and posterior ends of idiosoma, widely separated from each other (Figure 1C). PD greatly reduced, smaller than AD. Three pairs of platelets ventrally between AE and PE, the anterior-most wider than the others. AE with three pairs of setae, PE each with three setae. Palp three- or four- segmented. Trochanter III with one seta. Solenidion on tarsus I similar in length and thickness to dorsal setae on that segment (Figure 3A).

Genus Australacarus Bartsch


Type Species

Australacarus inexpectatus Bartsch, 1987, by monotypy and original designation.

Diagnosis

Body in non-compressed specimens greatly

J.C. Otto
Australacarus from northern Australia

Figure 1 *Australacarus longipalpus* sp. nov., adult. A, idiosoma, dorsal view; B, anterior dorsal plate; C, female idiosoma, ventral view; D, posterior epimeral plates and genitoanal plate of female; E, posterior epimeral plates and genitoanal plate of male. Scale bars: A, C, 100 μm; B, 25 μm; D, E, 50 μm.

anal cone, with pair of gland pores and with a series of canaliculi along anterior margin. Ventral platelets immediately posterior to AE four to five times as wide as long. GA usually with three pairs pgs, in one specimen two pgs on one side and three on the other (Figure 1D).

Gnathosomal base finely punctate (Figure 2E,F).

Pattern of pharyngeal plate as in Figure 2F. Palp three-segmented. P-1 and P-2 combined longer than gnathosomal base; P-2 delicately punctate, with small dorsal fissure anterior to seta.

All leg segments finely punctate. Chaetotaxy (trochanter – tibia): I 0-2-4-5-9 (Figure 3A), II 0-2-4-4-6 (Figure 3B), III 1-1-2-3-5 (Figure 3C), IV 1-1-4-4-
Figure 2  Australacarus longipalpus sp. nov. A, anterior ocular plate of female; B, posterior ocular plate of female; C, anterior ocular plate of male; D, posterior ocular plate of male; E, adult gnathosoma, dorsal view; F, adult gnathosomal base, ventral view; G, fused posterior dorsal plate and anal cone of deutonymph; H, genital plate of deutonymph; I, tibia I of deutonymph, ventromedial view; J, tibia II of deutonymph, dorsal view; K, telenemur IV of deutonymph, lateral view. Scale bars: A–D, 25 μm; E, F 50 μm; G–K, 25 μm.

6 (Figure 3D). Tibia I with ventromedial bipectinate seta but pectination sometimes barely visible depending on orientation, other legs without bipectinate setae. Solenidion on tarsus II heavier but shorter than that on tarsus I. Tarsus I with pair of doubled pas and two unpaired ventral setae. Tarsus II with pair of pas singlets and unpaired ventral seta. Tarsi III and IV with pair of pas singlets but without ventral seta. Paired claws of all legs with pecten along most of shaft and with accessory process. Median claw on legs I more clearly visible than those on other legs, including non-exposed part shorter than 1/4 of paired claws, median claws of legs II–IV rudimentary.

Male
Length unknown, specimen distorted. GA with seven pgs on one side of GO and nine pgs on the other side (Figure 1E); four pairs of sgs, two anteriorly, two posteriorly. All other characters as for female.

Deutonymph
Idiosoma 351 μm long. PD fused to anal cone (Figure 2G). GA with one pair pgs (Figure 2H). Tibia I with seven setae (Figure 2I). Tibia II with five setae (Figure 2I). Telenemur IV with two setae (Figure 2K). In all other characters as for female.
Australacars from northern Australia

Figure 3 Australacars longipalpus sp. nov., adult. A, leg I, lateral view; B, leg II, lateral view; C, leg III, medial view; D, leg IV, medial view. Scale bar: A-D, 100 μm.

Remarks
The only other known species of Australacars with four setae on telofemur IV is A. mesaktanus sp. nov. For differences between both species see the remarks to the latter.

A. longipalpus is known only from the Queensland Plateau. Whether it is absent on the Great Barrier Reef, which is less than 150 km away but separated from the Queensland Plateau by a more than 1000 m deep trough (Orme, 1977) is unclear. However, several species in the halacarid genera Acaromantis, Arhodeoporus, Copidognathus, Corallihalacars, Halacarellus, Halacars, Simognathus, Scaptognathides, Scaptognathus, and an undescribed genus (Otto, 1999, 2000a, 2000b; Otto, unpublished), are also known only from the Queensland Plateau and a pattern pointing towards a distinct halacarid fauna of the Queensland Plateau is beginning to emerge.

Etymology
The specific epithet refers to the species' relatively long palps.

Australacars mesaktanus sp. nov.
Figures 4, 5

Material Examined
Holotype
♂, QMS105563, Great Barrier Reef, 23°12.22'S 151°58.49'E, 27 August 1999, I. Zagorskis, coarse sand at 60 m.

Description
Female
Idiosoma 518 μm long. Membranous cuticle between plates papillate (Figure 4G). AD, PE and AE finely punctate. Posterior margin of AD drawn out into a thickened nose-like projection (Figure 4A); pair of gland pores and pair of setae in posterior half, pores slightly anterior to setae and each seta closer to a gland pore than to other seta.

Anterior OC (Figure 4C) more elongate than posterior OC (Figure 4D), anterior and posterior OC with several canaliculi and central subcuticular scar or cavity, posterior OC in addition with a pore. PD 14 μm long and 8 μm wide, distinctly narrower than 1/2 of anal cone (Figure 4B), with pair of gland pores and anteriorly with several canaliculi. Pair of ventral platelets immediately posterior to AE three to four times wider than long (Figure 4E). GA with three pairs pgs (Figure 4F).

Gnathosomal base finely punctate. Pattern of pharyngeal plate as in Figure 4H. Palp three-
Figure 4  *Australacarus mesaktamus* sp. nov., female. A, anterior dorsal plate; B, posterior dorsal plate and anal cone; C, anterior ocular plates, left and right respectively; D, posterior ocular plates, left and right respectively; E, anterior epimeral plate and ventral platelets; F, posterior epimeral plates and genitoanal plate; G, detail of membranous cuticle surrounding dorsal seta; H, ventral gnathosoma. Scale bar: A–H, 50 µm.

segmented, P-1 and P-2 combined shorter than gnathosomal base; P-2 finely punctate; anterior to insertion of seta with dorsal fissure.

All legs finely punctate. Chaetotaxy (trochanter–tibia): I 0-2-4-5-9 (Figure 5A), II 0-2-4-4-6 (Figure 5B), III 1-1-2-3-5 (Figure 5C), IV 1-1-4-4-6 (Figure 5D). Tibia I with ventromedial bipectinate seta (oil immersion), other legs without such seta. Solenidion on tarsus II heavier but shorter than that on tarsus I. Tarsus I with pair of doubled pas and two unpaired ventral setae. Tarsus II with pair of pas singlets and unpaired ventral seta. Tarsi III and IV with pair of pas singlets but no ventral seta. Paired claws of all legs with conspicuous accessory process and pecten along most of shaft. Median claw on all legs barely visible.

**Male**

Unknown.

**Remarks**

*A. mesaktamus* is closely related to *A. longipalpus* sp. nov. which also has four setae on telofemur IV, a single bipectinate seta on tibia I and an elongate anterior OC that lacks a pore. *A. mesaktamus* can be distinguished from *A. longipalpus* by the AD having a conspicuous posterior nose-like projection, the PD being narrower than 1/2 the width of the anal cone and P-1 and P-2 combined being shorter than the gnathosomal base.

**Etymology**

*mesaktos* [Gr.] = in mid ocean; referring to the species' occurrence in relatively deep water.

*Australacarus zagorskisae* sp. nov.

**Figures 6, 7**

**Material Examined**

**Holotype**

♂, QMS105564, Great Barrier Reef, 23°12.22'S 151°58.49'E, 27 August 1999, I. Zagorski, coarse sand at 60 m.

**Description**

**Male**

Idiosoma 531 µm long. Membranous cuticle between plates with numerous papillae (as for *A.
Figure 5 *Australacarus mesaktanus* sp. nov., female. A, leg I, lateral view; B, leg II, dorsolateral view; C, leg III, ventrolateral view; D, leg IV, lateral view. Scale bar: A–D, 50 μm.

*mesaktanus* in Figure 4G. AD punctate except for a transverse area anteriorly (Figure 6A). Posterior margin of AD convex, gland pores distinctly anterior of setae; distance between setae less than that between seta and gland pore. Anterior OC variable in shape within the single specimen (Figure 6B), slightly longer than wide, with central pore and numerous canaliculi, of which five or six are more conspicuous than others. Posterior OC (Figure 6C) with small pore and scattered canaliculi of which one or two are more conspicuous than others. PD slightly wider than long (Figure 6D), with few canaliculi, mostly in anterior half. AE covered with numerous canaliculi, those in a transverse anterior band finer than others; a gap anterior to insertions of legs I (arrow in Figure 6E) that exposes an epimeral pore. Platelets immediately posterior to AE minute, not distinctly wider than long, GA finely punctate, with 10 pgs on one side and 12 pgs on the other and four pairs of sgs.

Gnathosomal base finely punctate with pattern of pharyngeal plate as in Figure 6G. Palp three-segmented. Segment P-2 shorter than gnathosomal base; with a narrow furrow surrounding the entire segment anteriorly; canaliculi proximal to furrow coarser than those distal to it.

All legs finely punctate. Chaetotaxy (trochanter – tibia): I 0-2-4-5-10 (Figure 7A), II 0-2-4-4-6 (Figure 7B), III 1-1-2-3-5 (Figure 7C), IV 1-1-2-4-7 (Figure 7D). Tibia I with two bipectinate setae (oil immersion). Solenidion on tarsus II heavier but shorter than that on tarsus I. Tarsus I with pair of doubled pas and two unpaired ventral setae. Tarsi II–IV with pair of pas singlets but no ventral seta. Paired claws of all legs with conspicuous accessory process, pecten along most of shaft on legs II–IV, no pecten seen on claws of leg I. Median claw of all legs minute, scarcely protruding.

**Female**

Unknown.

**Remarks**

*A. zagorskisae* is similar to *A. inexpectatus* and *A. pustulatus* in having two setae on telofemur IV and a pore on the anterior OC. It differs from *A. inexpectatus* by lacking a conspicuous posterior protrusion on the AD, having a three- rather than four -segmented palp, two instead of three ventral setae on tarsus I, and 22 instead of ca. 50 pgs in the male. Differences are also present in leg chaetotaxy, according to Bartsch’s (1987) illustrations *A.
\textit{Australacarus} pustulatus Bartsch, 1993: 65.

Material Examined


Description

\textit{Larva}

Idiosoma 252 µm long. AD with pair of gland pores and pair of setae, both posteriorly at same level; posterior margin convex (Figure 8A). Both pairs of OC more or less round, the anterior pair much larger than the posterior one and with a conspicuous pore. PD and anal cone fused (Figure 8B).
Australacarus

from northern Australia

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Figure 7  Australacarus zagorskisae sp. nov., male. A, leg I, medial view; B, leg II, ventromedial view; C, leg III, ventromedial view; D, leg IV, ventromedial view. Scale bar: A–D, 50 μm.

8C), with two pairs of setae and pair of gland pores. AE with two pairs of setae, PE with one seta. Two pairs of closely associated platelets immediately posterior to AE, two further pairs of platelets more posterior.

Ventral gnathosomal base with two pairs of setae (Figure 8D). Palp three-segmented, P-2 with a well developed dorsal seta (Figure 8E), P-3 with three basal setae and a closely associated pair of spurs apically.

Leg chaetotaxy (trochanter – tibia): I 0-4-4-5 (Figure 9A), II 0-4-4-5 (Figure 9B), III 1-3-3-5 (Figure 9C). Tarsus I with three dorsal setae, three ventral setae and pair of doubled pas. Tarsus II with three dorsal setae, pair of ventral setae and one unpaired lateral pas, tarsus III with three dorsal setae and pair of ventral setae but no pas.

Remarks

The above listed specimens include the first records of A. pustulatus from tropical northeastern and northwestern Australia. Rottnest Island in southwestern Western Australia, the only other known location of A. pustulatus, is situated much further south at 32°S but is bathed by the warm south-flowing Leeuwin Current, which is known to support a rich tropical fauna (Hutchins and Pearce, 1994). Thus A. pustulatus may be a predominantly tropical species. However, further collecting in the southern part of the continent is needed to support this hypothesis.

Most of the characters of the A. pustulatus larva and the differences between it and the adult are those usually encountered in halacarids (see Bartsch, 1998b). For example, a genital opening is
absent, basifemur and telofemur are not yet separated, the dorsal seta corresponding to that on the basifemora of later instar is not yet developed, two instead of three setae are present on the AE, and one instead of three setae are present on the PE. However, unusually for halacarids, in *Australacarus pustulatus* the PD possesses a pair of setae (ds-5) (Figure 8C) that in the later instar moves into the membranous cuticle (Figure 1A). In other halacarids the opposite is usually the case, i.e. the PD increases in relative size and accommodates setae that in the larva are found in the membranous cuticle (Bartsch, 1998b).

**Figure 8** *Australacarus pustulatus* Bartsch, larva. A, idiosoma, dorsal view; B, idiosoma, ventral view; C, posterior dorsal plate and anal cone (fused); D, gnathosomal base, ventral view; E, palp, lateral view. Scale bars: A, B, 100 μm; C–E, 25 μm.

**Key to species of Australacarus (adults)**

1. Median claw on all legs ca. 1/2 length of the paired claws (Figure 11 in Bartsch, 1993); tibia II with five setae, genu IV with three setae
   
   *A. pustulatus* Bartsch

2. Telofemur IV with two setae, anterior OC with pore (Figure 6B); pair of ventral platelets
Australacarus from northern Australia

immediately posterior to AE no wider than twice their length (Figure 6E) ........................................ 4
Telofemur IV with four setae, anterior OC without pore (Figures 1A, 4C); pair of ventral platelets immediately posterior to AE at least three times wider than long (Figures 1C, 4E) ....................................................... 3

3. Palp segments P-1 and P-2 combined shorter than gnathosomal base (Figure 4H); AD with posterior nose-like projection (Figure 4A); PD narrower than 1/2 the width of anal cone (Figure 4B) ........................., A. mesaktanus sp. nov.
Palp segments P-1 and P-2 combined longer than gnathosomal base (Figure 2E); posterior margin of AD convex (Figure 1B); PD wider than 1/2 the width of the anal cone (Figure 1A) ............................., A. longipalpus sp. nov.

4. AD posteriorly drawn out into a pointed protuberance (Figure 4 in Bartsch, 1987); 13 setae on tibia I, 11 setae on tibia II, and nine setae on tibia IV .........., A. inexpectatus Bartsch
AD posteriorly convex (Figure 6A); ten setae on tibia I, six setae on tibia II, and seven setae on tibia IV ............... A. zagorskisae sp. nov.

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REFERENCES


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A new species of false antechinus (Marsupialia: Dasyuromorphia: Dasyuridae) from the Pilbara region, Western Australia

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Abstract - *Pseudantecliinus roryi* sp. nov. from the Pilbara region of Western Australia is described. The new species is close genetically to *P. macdonnellensis* but differs from that species and all other members of the genus in aspects of cranial, dental and external morphology. *Pseudantecliinus roryi* is found in regional sympatry with *P. woolleyae*, but is narrowly allopatric with *P. macdonnellensis* of the central Australian uplands. A revised generic diagnosis of *Pseudantecliinus* is given and the phylogenetic position of *Pseudantecliinus* within the Dasyurinae is discussed.

INTRODUCTION
Knowledge of the taxonomic diversity of the false antechinuses has expanded greatly over the last three decades, with the description of *Pseudantecliinus woolleyae* from mid-western and Pilbara regions of Western Australia (Kitchener and Caputi, 1988) and *P. ningbing* from the Kimberley region (Kitchener, 1988), and reinstatement of *P. mimulus* Thomas from the northeastern Northern Territory (Kitchener, 1991). These species were all previously included within or synonymized under *Pseudantecliinus macdonnellensis* (Spencer), which has more recently been restricted to the uplands of Central and Western Australia. The species *bilarni* has also been included within *Pseudantecliinus* by some workers (Kitchener and Caputi, 1988), while others have grouped *bilarni* with *apicalis* from southwestern Australia under the genus *Parantechinus* Tate (Archer, 1982; Woolley and Begg, 1998).

In this paper we examine patterns of morphological and genetic variation within *Pseudantecliinus macdonnellensis*. Our results show that western and central populations of *P. macdonnellensis* are readily distinguished on both craniodental and external criteria, with no evidence of clinal intergradation or obvious interspecific interaction where their ranges abut. Although these two forms display only a low level of genetic differentiation, they are nevertheless diagnosable by their allozyme profiles. We herein describe the western populations as a new species closely related to, but distinct from, *P. macdonnellensis*. Our broader comparative studies support Kitchener and Caputi's (1988) concept of *Pseudantecliinus* that includes *P. bilarni* (Johnson) but excludes *Parantechinus apicalis* (Gray). We provide a revised generic diagnosis for the genus *Pseudantecliinus*.

MATERIALS AND METHODS

Morphological Study
A total of 75 specimens of *Pseudantecliinus* were measured in this study. These included 10 individuals of *P. macdonnellensis* from the general region of the type locality, MacDonnell Ranges in the Northern Territory; 21 individuals referred to *P. macdonnellensis* from nine localities in Western Australia; and 20 individuals referred to the new species from six localities in northwestern and central Western Australia. Samples of *P. woolleyae* (*n* = 16) and *P. mimulus* (*n* = 8) were included in the statistical analysis. Multiple specimens of *P. ningbing* and *P. bilarni* and representatives of other dasyurine genera (*Myoictis, Dasycercus, Dasyuroides, Dasyurus, Parantechinus, Dasykaluta*) were examined for purposes of morphological comparison. Table 1 lists all individuals used in the statistical analysis by species and locality.

Tooth numbering follows Luckett (1993). Skull measurements are illustrated in Figure 1. All skull and external measurements are given in mm. The measurements are: GSL, Greatest Skull Length; BL, Braincase Length; BW, Braincase Width; ZW, Zygomatic Width; LIW, Least Interorbital Width; POB, Post Orbital Breadth; TWAW, Tympanic Wing of Alisphenoid Width; TWAL, Tympanic Wing of Alisphenoid Length; EW, Ectotympanic Width; BT, Bulla Total Length (periotic + alisphenoid); BP, Bulla Periotic Length; WOB, Width outside Bullae; WIB, Inter-bullar Width; WOB, Width outside Bullae; WIB, Inter-bullar Width; C'M'M', Distance from Upper Canine to end of Upper Molar 4; I'M'M', Upper Molar Row Length; LM'RM', Width across outside of Upper Right and Left Molar 3; MLTD, Distance between Pterygoids; MLPV, Maxillary Vacuity Length; PAL, Length of Palate; DL, Dentary Length; I,M', Distance from First Lower Incisor to
Figure 1 Cranial, tooth and dentary measurements.

Lower Molar 4; APAC, Distance from Angular Process to Articular Condyle; ACAR, Distance from Articular Condyle to anterior margin of Ascending Ramus; SV, Snout-Vent Length; TV, Tail-Vent Length; EAR, Ear Length; TR, Tragus Length; PESL, Pes Length (minus claw); PESW, Width of Pes at base of Hallux.

Skulls were categorized into three age groups (juvenile, adult, mature), according to dental eruption, extent of toothwear, and fusion of cranial sutures. Most individuals fell into the adult class. Sexual maturity was confirmed by examination of external reproductive structures. Sex of the specimen was determined from the body or from information recorded with the skull.

All measurements (Table 2a, b) were recorded with digital calipers and all statistical analysis was carried out using Genstat 5 (Genstat 5 Committee, NAG, 1993).

Genetic Study
Genetic profiles were established by allozyme electrophoresis of liver homogenates on cellulose acetate gels (CellogelO), based on procedures described in Richardson et al. (1986). Four individuals from two localities in northwestern Australia were compared with seven individuals from seven localities in northern South Australia.

The following enzymes and proteins were scored: aconitate hydratase (ACON, EC 4.2.1.3), acid phosphatase (ACP, EC 3.1.3.2), aminoacylase (ACYC, EC 3.5.1.14), adenosine deaminase (ADA, EC 3.5.4.4), alcohol dehydrogenase (ADH, EC 1.1.1.1), adenylate kinase (AK, EC 2.7.4.3), albumin (ALB, non-enzymatic plasma protein), aldehyde dehydrogenase (ALDH, EC 1.2.1.5), alkaline phosphatase (AP, EC 3.1.3.1), carbonate dehydratase (CA, EC 4.2.1.1), diaphorase (DIA, EC 1.6.99.), enolase (ENO1, EC 4.2.1.11), esterase (EST, EC 3.1.1.4), fructose-bisphosphatase (FDP, EC 3.1.3.11), fumarate hydratase (FUM, EC 4.2.1.2), guanine deaminase (GDA, EC 3.5.4.3), glutamate dehydrogenase (GDH, EC 1.4.1.3), glucose dehydrogenase (GLDH, EC 1.1.1.47) lactoyl-
A new species of false antechinus

Table 1

<table>
<thead>
<tr>
<th>Locality, latitude, longitude, sex (m=male, f=female and u=unknown) and Registration number (WAM, Western Australian Museum; U=Museum of Northern Territory) of animals measured.</th>
</tr>
</thead>
</table>

**P. mimulus**
Northern Territory: Centre Island, 15°41’00”S, 136°46’00”E, 3f, U1460, U1573, U1438; North Is, 15°34’00”S, 136°52’00”E, 2f, U1439, U0712; South West Is, 15°43’00”S, 136°40’00”E, m, U1437, f, U1463; Tambirini, 16°16’48”S, 134°19’12”E, f, U1212.

**P. roryi** sp. nov.
Western Australia.
Clutterbuck Hills, 24°35’00”S, 126°17’00”E, m, WAM M17446; Eginbah Hmsd, 2r00’00”S, 126°00’00”E, f, WAM M4291; Great Sandy Desert, 22°27’00”S, 132°54’00”E, m, WAM M22691; Mundabullangana Hmsd, 20°42’00”S, 118°17’00”E, f, WAM M4483; Woodstock Station, 21°36’30”S, 118°57’30”E, m, WAM M5280, f, WAM M5511; 21°37’00”S, 118°57’00”E, f, WAM M34228, 21°36’45”S, 118°53’30”E, m, WAM M34289, WAM M34290; 21°36’45”S, 118°53’30”E, m, WAM M34282, 21°36’45”S, 118°53’30”E, m, WAM M34288, 21°37’00”S, 118°53’30”E, f, WAM M34304, 3f, WAM M34339, WAM M3440-1; Yardie Well, 22°19’30”S, 113°48’30”E, f, WAM M18139.

**P. macdonnellensis**
Northern Territory
Billack, 24°ir00”S, 132°26’00”E, m, U1738, Chewings, 23°54 00S, 132°32’24”E, f , U1088, 2m, U1090, U1093; Kathleen, 24°14’24”S, 132°24’00”E, m, U1756; Milton Peak, 23°22’48”S, 133°24’00”E, m, U1113; Windajong, 21°18’00”S, 132°3r48”E, m, 1750, f, U1749; Narwietoom, 23°18’36”S, 132°29’24”E, m, UlllO; Tennant Creek, 19°39’00”s, 134°15’00”E, f, U6289; Arapanya Stn, 22°19’00”S, 133°22’00E, f, U1289.

**P. woolleyae**
Western Australia.
Barlee Range Nature Reserve, 23°45’00”S, 116°20’00”E, m, WAM M3478, 23°06’21”S, 115°59’52”E, m, WAM M41840, 23°05’45”S, 116°00’35”E, m, WAM M43369; Barton Mine, 21°36’20”S, 117°07’30”E, f, WAM M24151; Mardie Hmsd, 21°15’00”S, 116°07’40”E, m, WAM M19676; Marynia, 25°10’00”S, 119°50’00”E, m, WAM M37023; Millstream, 21°35’00”S, 117°04’00”E, f, WAM M29292; Gill Pinnacle, 24°54’00”S, 126°49’00”E, 3m, WAM M23135; Gibson Desert, 25°03’00”S, 124°59’00”E, f, WAM M2897, WAM M8930, 3f, WAM M8931-3, 26°00’00”S, 127°45’30”E, f, WAM M34277, 25°45’00”S, 126°11’00”E, f, WAM M14669; Winduldurra Rockhole, 26°31T5”S, 126°30’30”E, m, WAM M13855.

**glutathione lyase (GLO, EC 4.4.1.5), aspartate aminotransferase (GOT, EC 2.6.1.1), glycerol-3-phosphate dehydrogenase (GPD, EC 1.1.1.8), glucose-6-phosphate isomerase (GLP, EC 5.3.1.9), glutathione peroxidase (GPX, EC 1.11.1.9), 3-hydroxybutyrate dehydrogenase (BHBD, EC 1.1.1.30), isocitrate dehydrogenase (IDH, EC 1.1.1.42), cytosol aminopeptidase (LAP, EC 3.4.11.1), L-lactate dehydrogenase (LDH, EC 1.1.1.27), malate dehydrogenase (MDH, EC 1.1.1.37), ‘malic’ enzyme (ME, EC 1.1.1.40), mannose-6-phosphate isomerase (MPI, EC 5.3.1.8), dipeptidase (valine-leucine) (PEPA, EC 3.4.13.*), tripeptide aminopeptidase (leucine-glycine-glycine) (PEPB, EC 3.4.11.), proline dipeptidase (phenylalanine-proline) (PEPD, EC 3.4.13.*), phosphoglycerate mutase (PGAM, EC 5.2.4.1), 6-phosphogluconate dehydrogenase (6PGD, EC 1.1.1.44), phosphoglycerate kinase (PGK, EC 2.7.2.3), phosphoglucomutase (PGM, EC 5.4.2.2), pyruvate kinase (PK, EC 2.7.1.40), superoxide dismutase (SOD, EC 1.15.1.1), L-iditol dehydrogenase (SORDH, EC 1.1.1.14), triose-phosphate isomerase (TPI, EC 5.3.1.1). The nomenclature for referring to enzymes, loci and allozymes follows Adams et al. (1987). Genetic distances were calculated as either percentage fixed differences (%FD, Richardson et al., 1986) or corrected Nei distance (Nei, 1978).

**Canonical Variate Analysis (CVA)**
Analysis of cranial and external variables was carried out separately, but the same statistical procedure was used for both sets of variables. Initially, multiple regression was used to investigate variation due to sex, age and species differences for each of the 23 cranial and 6 external characters. These analyses checked for normality and detected statistical outliers which were then re-checked for measurement accuracy. Each variable was regressed on sex, age and species.
Table 2a  Measurements in mm for Skull Variables by sex. N, Sample size; X, mean; Min, minimum; Max, maximum; SD, standard deviation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>GSL</th>
<th>BL</th>
<th>BW</th>
<th>ZW</th>
<th>LIW</th>
<th>POB</th>
<th>TWAW</th>
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<tr>
<td>P. minules</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>17</td>
<td>7 1 7 1 8</td>
<td></td>
<td>1 8</td>
<td>1 8</td>
<td>1 8</td>
<td>1 8</td>
</tr>
<tr>
<td>X</td>
<td>24.75 24.87</td>
<td>23.00 23.21</td>
<td>10.90 11.05</td>
<td>15.00 14.96</td>
<td>5.750 5.472</td>
<td>5.740 5.606</td>
<td>4.220 4.130</td>
</tr>
<tr>
<td>Min</td>
<td>24.75 24.28</td>
<td>23.00 22.50</td>
<td>10.90 10.60</td>
<td>15.00 14.36</td>
<td>5.750 5.330</td>
<td>5.740 5.400</td>
<td>4.220 3.600</td>
</tr>
<tr>
<td>Max</td>
<td>24.75 25.57</td>
<td>23.00 23.87</td>
<td>10.90 11.32</td>
<td>15.00 15.59</td>
<td>5.750 5.770</td>
<td>5.740 5.770</td>
<td>4.220 4.500</td>
</tr>
<tr>
<td>SD</td>
<td>* 0.266</td>
<td>* 0.3532</td>
<td>* 0.0740</td>
<td>* 0.1724</td>
<td>* 0.02014</td>
<td>* 0.01466</td>
<td>* 0.08660</td>
</tr>
</tbody>
</table>

P. roysi sp. nov.

| N | 7 7 7 7 7 9 7 8 7 7 7 7 7 7 7 7 8 |
| X | 26.45 25.84 | 25.14 24.41 | 11.21 11.02 | 16.00 15.41 | 5.674 5.339 | 5.212 5.021 | 4.779 4.671 |
| SD | 0.5868 0.723 | 0.4828 0.9448 | 0.0458 0.2797 | 0.3250 0.5672 | 0.04733 0.18627 | 0.04257 0.13497 | 0.04132 0.06403 |

P. macdonnellensis

| N | 16 8 16 8 17 9 9 17 9 19 9 19 9 19 9 19 9 19 9 19 9 |
| Min | 25.67 25.50 | 23.93 23.27 | 11.49 10.93 | 15.04 14.79 | 5.610 5.050 | 5.090 4.810 | 3.970 3.900 |
| SD | 0.5868 0.723 | 0.4828 0.9448 | 0.0458 0.2797 | 0.3250 0.5672 | 0.04733 0.18627 | 0.04257 0.13497 | 0.04132 0.06403 |

P. woolleyae

| N | 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 |
| SD | 0.282 | 2.143 | 0.9367 | 1.6489 | 0.8442 | 0.1017 | 0.6772 | 0.3179 | 0.12133 | 0.10063 | 0.00583 | 0.06172 | 0.08682 | 0.07083 |

LM4RM4 ML1D MLPV PAL DL I1M4 APAC ACAR
| 1 8 | 1 8 | 1 8 | 1 8 | 1 8 | 1 8 | 1 8 |
| * 0.04466 | * 0.01782 | * 0.0642 | * 0.1847 | * 0.6263 | * 0.1977 | * 0.07237 | * 0.067 |

The extent of interactions between these factors was investigated for any evidence of interdependence. Two cranial variables, APAC and BW, showed significant interactions (p = 0.001, d.f.=2 and 0.005, d.f.=2 respectively) between sex and age. Two other cranial variables showed minor interaction between sex and age (BL; p = 0.035, d.f.=2) and species and age (MLPV; p = 0.030, d.f.=4) respectively. External measurements were taken on a reduced number of animals that did not permit testing of all potential interactions between species, sex and age. One external variable showed minor interactions between sex and age (TV; p = 0.023, d.f.=1). The variables
A new species of false antechinus which showed significant interactions were not used in further analyses.

For cranial variables, females were significantly smaller than males in all species; only EW, BP, WIB, MLTD showed no statistically significant sexual dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). 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Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). 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Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3). No external variable showed significant sexual dimorphism. Regression dimorphism (Table 3).
Table 2b: Measurements in mm for externals. N, Sample size; X, mean; Min, minimum; Max, maximum; SD, standard deviation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>SV</th>
<th>TV</th>
<th>EAR</th>
<th>TRAGUS</th>
<th>PESL</th>
<th>PESW</th>
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<tbody>
<tr>
<td>N. P. roryi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
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<td>Max</td>
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<td></td>
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</tbody>
</table>

| P. macdonnellensis | | | | | | |
| N | | | | | | |
| Min | | | | | | |
| Max | | | | | | |
| SD | | | | | | |

| P. roryi sp. nov. | | | | | | |
| N | | | | | | |
| Min | | | | | | |
| Max | | | | | | |
| SD | | | | | | |

| P. wooli | | | | | | |
| N | | | | | | |
| Min | | | | | | |
| Max | | | | | | |
| SD | | | | | | |

Table 3: Probabilities from regression of variables, species, sex, age: testing for interactions.

<table>
<thead>
<tr>
<th>Variable</th>
<th>species</th>
<th>sex</th>
<th>age</th>
<th>species/sex</th>
<th>species/age</th>
<th>sex/age</th>
<th>species/sex/age</th>
</tr>
</thead>
<tbody>
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<td>GSL</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
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<td>BL</td>
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<td></td>
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<td>0.775</td>
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<td>0.263</td>
</tr>
<tr>
<td>ZW</td>
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<td>0.950</td>
</tr>
<tr>
<td>LW</td>
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<td></td>
<td></td>
<td>0.775</td>
</tr>
<tr>
<td>L'OB</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.854</td>
</tr>
<tr>
<td>TWAW</td>
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<td>0.007</td>
</tr>
<tr>
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<tr>
<td>C'M</td>
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<td>0.894</td>
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<td>0.320</td>
</tr>
<tr>
<td>LM</td>
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<td>0.551</td>
</tr>
<tr>
<td>APAC</td>
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<td>0.148</td>
</tr>
<tr>
<td>ACAR</td>
<td>0.039</td>
<td></td>
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<td></td>
<td></td>
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<td>0.672</td>
</tr>
<tr>
<td>SV</td>
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<td></td>
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<td>0.427</td>
</tr>
<tr>
<td>TV</td>
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<td></td>
<td></td>
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<td>0.023</td>
</tr>
<tr>
<td>EAR</td>
<td>0.006</td>
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<td>0.265</td>
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<td>TRAGUS</td>
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<td>0.166</td>
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<td>PESL</td>
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<td>0.072</td>
</tr>
<tr>
<td>PESW</td>
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<td>0.628</td>
</tr>
</tbody>
</table>
Table 4. Skulls. Canonical Variate Analysis scores, grouping by species (P. macdonnellensis, P. mimulus, P. woolleyae, P. roryi sp. nov.).

<table>
<thead>
<tr>
<th>variable</th>
<th>SC1</th>
<th>SC2</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWAL</td>
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<td>0.1352</td>
</tr>
<tr>
<td>C1M5</td>
<td>0.2001</td>
<td>0.7781</td>
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<tr>
<td>POB</td>
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<td>0.5634</td>
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<tr>
<td>WIB</td>
<td>-0.4835</td>
<td>0.5217</td>
</tr>
<tr>
<td>NASL</td>
<td>0.1375</td>
<td>0.4179</td>
</tr>
</tbody>
</table>

macdonnellensis and P. sp. nov., despite the overlap in their longitudinal ranges.

Finally, to verify the species groupings, Canonical Variate Analysis was carried out with a priori grouping by location rather than by species. Using the regression coefficients for all variables, the data for this analysis were transformed by removing age and sex differences while retaining the interlocation variation. The resultant plots were essentially identical to those produced using a priori grouping by species. All of the above analyses were also replicated using untransformed data. The grouping by location rather than by species. All of the above analyses were essentially the same in all cases. A CVA of P. macdonnellensis and P. sp. nov., with a priori grouping by species, produced a complete separation of CV scores. The most significant discriminating variables were GSL, WIB, TWAL, WOB and ACAR. (Table 5).

To assist with quick diagnosis of skulls, various bivariate distributions were examined. The two most informative plots are GSL against C1M4 (Figure 5a), reflecting a difference in relative tooth size between the two taxa, and GSL against WIB (Figure 5b), reflecting the difference in degree of inflation of the auditory bulla.

Results of Allozyme Analysis

A total of 53 putative loci were scorable in the present study. Table 6 presents the allozyme profile at 11 variable loci of seven specimens of Pseudantechinus macdonnellensis and four specimens of Pseudantechinus sp. nov. The following 42 loci were invariant: Acon1, Acon2, Acp, Acye, Ada2, Adh1, Ak1, Ak2, Aldh, Ap1, Ap2, Ca, Dia2, Enol, Est1, Est2, Fdp, Fum, Gda, Gdh, Glo, Got2, Gpd1, Gpd2, Gpi, Gpx, Hbdh, Idh1, Idh2, Lap, Mdh2, PepA, PepD, Pgam, Pgd, Pkg, Pgm, Pkl, Pk2, Sod, Sordh, and Tpi.

As is typical for dasyurids, the allozyme data reveal low levels of within-taxon genetic variation. Eighty-five percent of all loci were invariant in at least one taxon and all but one of the variable loci (Gldhi) displayed only two alleles. The estimates of direct count heterozygosity were Ho = 0.027 ± 0.013 for P. macdonnellensis and Ho = 0.047 ± 0.017 for P. sp. nov.

Despite the large number of loci screened, only one fixed difference was observed, at the Me locus. In addition, the Mpi locus was nearly fixed for alternate alleles, with a single heterozygous individual from Nifty Mine in the Great Sandy Desert. No other significant differences in allele frequency were present. Although individuals can be unequivocally diagnosed by their genetic profiles at the two key loci, the overall level of genetic differentiation between the two taxa is low (2% fixed differences; Nei D = 0.033).

The seven individuals of P. macdonnellensis showed no clear evidence of genetic differentiation across the range of sampling localities. Similarly, there are no indications of genetic heterogeneity between the two specimens of P. sp. nov. from Nifty Mine and the two from Woodstock Station. Although these represent very small samples on which to examine within-taxon genetic divergence, it is important to note that increasing sample sizes does not generally produce a significant increase in either Nei's D or % FD between two sample sets. Of course, sampling of additional localities might always lead to the discovery of new dimensions of genetic variation, a problem shared by all forms of systematic analysis.

Summary of Morphological and Genetic Comparisons

The combined morphological and genetic data indicate that the northwestern Pseudantechinus populations are both distinct and diagnosable from central Australian P. macdonnellensis. Despite their ease of morphological separation, the allozyme data demonstrate a close sibling relationship between the two taxa.

The decision to recognise the northwestern population as a distinct species rather than a geographic race of P. macdonnellensis has been taken for several reasons. Most important is the observation that both taxa maintain their distinct morphological identities over substantial geographic ranges, and show no indication of clinal intergradation or interspecific interaction in central Western Australia where their ranges approach to within 140 km. Further, the multivariate analysis indicates that the crania of the two taxa differ more in 'shape' than in size, suggesting possible dietary and other ecological differences between them.
Lastly, whilst the allozyme data by themselves are not compelling as to their specific status, they do document a level of genetic divergence consistent with that found for other sibling species of dasyurid (Baverstock et al., 1982).

Further investigation could usefully focus on the issue of mitochondrial DNA lineage segregation between the northwestern population and \textit{P. macdonnellensis}, and on the zone of potential parapatry/sympatry in the area south of the Clutterbuck Hills.

**SYSTEMATICS**

\textit{Pseudantechinus} Tate, 1947: 139.

Revised generic diagnosis

\textit{Pseudantechinus} differs from all other genera of
A new species of false antechinus

Dasyurinae in possession of a broad, flattened braincase; minimal development of sagittal crest; and reduction in size of upper and lower canines (Figure 6). It further differs from *Parantechimus* in having a shorter facial skeleton (Figure 7); more extensive fenestration of maxillary and palatine portions of palate; lack of postorbital process on frontal; greater degree of inflation of the middle ear cavity; lack of enlargement of P3; greater degree of reduction of M2-3 talonids; loss of M5-3 protoconules; and less procumbent P. It further differs from *Myoictis* in having a shorter facial skeleton; lack of postorbital process on frontal; far greater degree of inflation of the middle ear cavity; presence of broad maxillary shelf forming floor to orbital fossa; lack of reduction of transverse canal in basisphenoid; reduction in width and interruption of anterior cingula and loss of protoconules on M1, greater degree of reduction of M1 protocone; and greater degree of reduction of M1,2,3 entoconids and of M1,4 talonids. It further differs from *Dasycercus* and *Dasyuroidea* in the less extreme shortening of the facial skeleton; less extreme fenestration of palatine portion of palate; less extreme reduction of M3 paraconid; and greater degree of reduction of buccal cingulids on M3. It further differs from *Dasykaluta* in less extreme shortening of facial skeleton; nasal not greatly broadened posteriorly;

Figure 4  CV1 vs Longitude. CVA grouped by species, labelled by location. See figure 3 for key.

Table 6  Allozyme profiles of *Pseudantechinus macdonnellensis* and *P. roryi* sp. nov.

<table>
<thead>
<tr>
<th>Regno</th>
<th>Locality</th>
<th>Ada1</th>
<th>Adh2</th>
<th>Alb</th>
<th>Dia1</th>
<th>Gldh</th>
<th>Got1</th>
<th>Ldh</th>
<th>Mdhl</th>
<th>Me</th>
<th>Mpi</th>
<th>PepB</th>
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<td>b</td>
<td>ab</td>
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retention of small to moderate-sized $P'$; and greater degree of reduction of buccal cingulids on $M_{1,3}$. It further differs from *Dasyurus* (sensu lato) in absence of postorbital process on frontal; greater degree of inflation of the rostral tympanic process of petrosal; retention of small to moderate-sized $P'$; lack of enlargement of $P^3$; reduction in width and interruption of anterior cingula and loss of protoconules on $M^1$; and greater degree of reduction of $M_{1,3}$ entoconids. It further differs from *Sarcophilus* in less extreme broadening of temporal fossa and lateral flaring of zygomatic arch; less extreme shortening of the facial skeleton; greater degree of fenestration of the palatal portion of palate; greater degree of inflation of the rostral tympanic process of petrosal; non-transverse orientation of the upper incisor series; retention of small to moderate-sized $P'$; less extreme
enlargement of metastylar corner of $M^{3+4}$; less extreme reduction of $M_{1,4}$ paraconid; lack of posterior displacement of $M_{1,4}$ metaconids; and less extreme reduction of $M_{1,4}$ talonids and $M^{3+3}$ protocones.

**Pseudantechinus roryi** sp. nov.

**Material Examined**

**Holotype**

Western Australian Museum catalogue number M34277: adult male; carcass fixed in 4% formalin, preserved in 75% ethanol; skull and dentaries separate. Caught in an Elliott trap by R. A. How et al. on 29 July 1990.

**Paratypes**

See specimens examined.

**Type Locality**

Woodstock Station, 500 metres north of the homestead, in 21°36'42"S, 118°57'20"E.

**Habitat**

Low open woodland of *Acacia pyrifolia* (2-3 m tall, 3% canopy cover), *Hakea suberea* (2-3 m tall, <0.5% canopy cover) and *Acacia* sp. (2-3 m tall, <0.5% canopy cover) over *Triodia* spp. (c. 0.5 m tall, 80% canopy cover). Soil a coarse sandy-loam with granite bedrock at 30-40 cm (How et al., 1990).

**Diagnosis**

*Pseudantechinus roryi* (Figures 8-10) differs from all other species of *Pseudantechinus* in having the following combination of characters: maxillary palatal vacuity expanded anteriorly either to level
of metastyle or to protocone on M¹; anterior root of zygomatic arch with shallow muscular fossa; P¹ single-rooted, lower and smaller in crown area than both P¹ and P²; P² slightly taller and larger in crown area than P¹; M¹ with conical paracone, lacking preparacrista and stylar cusp B (StB); M¹⁺ anterobuccal cingula broad but reduced in lateral extent; M² + with small stylar cusp E (StE); P; absent; P₃ subequal in height and crown area to P₂; M₃ paraconid and metaconid both extremely reduced; M₁ lacking entoconid; M₂ + with vestigial entoconids; and M₂⁺ with narrow precingulids and poorly developed parastylids; penis with elongate ventral process presumably formed from accessory corpora cavernosa; pouch of female with six teats.

Description

Skull and Dentary

Braincase low but gently rounded; lambdoidal crest distinct but not overhanging occipital surface of skull; temporal ridges low but distinct, converge posteriorly and usually meet in older individuals

Figure 7  Lateral view of skulls of (a) Pseudantechnus macdonnellensis, (b) P. bilarni, (c) Dasykaluta rosamondae, (d) Parantechnus apicalis and (e) Myoictis melas. All scale lines = 1 cm.
to form short sagittal crest at rear of skull; squamosal contacts frontal on lateral wall of braincase in 71% of sample, excluded from contact in remaining specimens by narrow alisphenoid-parietal contact (average length 0.62 mm); interorbital region flattened, lateral margins converge slightly to rear; postorbital processes absent; cranium attains maximum width just forward of glenoid fossae.

Rostrum moderately elongate and not markedly inflated; nasals broadest at point of intersection of maxillo-frontal suture, narrowing to front; anterior palatal foramina extend from $I^1$ to middle of $C^1$; maxillary palatal vacuity located between $M^1$
metacone and posterior end of $M'_2$; palatine palatal vacuity small, occasionally absent. Anterior root of zygomatic arch with poorly developed muscular fossa (for $M. maxillonosolabialis$), only weakly enclosed dorsally by out-turned ventral border of orbit.

Auditory region showing prominent inflation of auditory bulla, formed through pneumatization of alisphenoid, periotic, exoccipital and squamosal bones. Alisphenoid hypotympanic wing globular, expanded well forward of line drawn between anterior border of glenoid fossae; lateral edge almost completely enclosing thickened meatal process of ectotympanic. Rostral and caudal hypotympanic wings of petrosal together form a distinct posterior component of the 'bulla'; small paroccipital process of exoccipital encloses small extension of posterior pneumatic chamber; squamosal epitympanic sinus expanded laterally such that braincase width measured across squamosals is only slightly less than maximum skull width across zygomatic arches; postglenoid process of squamosal relatively high but transversely narrow; anterolateral wall of alisphenoid hypotympanic wing lacks bony spur for attachment of glenoid capsular ligament.

Cranial foramina show typical dasyurid arrangement (Archer, 1976b); bilateral transverse canal foramina relatively large and with distinct lateral sulci.

Ascending ramus of dentary inclined posteriorly, bearing elongate coronoid process; distance between tip of coronoid process and articular condyle much less than that between articular condyle and tip of slender angular ramus.

**Dentition**

$I'_1$ tallest of upper incisors, separated from rest of series by diastema; $I'_1$ crown project forward and medially but remain separated at tips; $I'_1$, $I'_2$ and $I'_3$ all subequal in crown height and length, forming regular series, crown apices posteroventrally directed; $I'_3$ separated from $C'_1$ by diastema equal in length to combined $I'_4$ crown lengths; $C'_1$ vertically oriented, usually with weak buccal and lingual cingula terminating in distinct anterior and posterior basal cuspules; no diastema between $C'_1$ and $P'_1$ or within upper premolar series; $P'_1$ and $P'_2$ similar in form with well developed buccal cingulum and associated anterior and posterior cuspules; $P'_2$ slightly taller and larger in crown area than $P'_1$; $I'_3$ slightly larger than $P'_3$; $P'_3$ each with two clearly distinct roots; $P'_3$ usually present,
A new species of false antechinus

approximately one third crown area of $P^1$ and with single root; $StB$ very low and indistinct on $M^2$; preparacrista very short; $StD$ taller than $StB$ on $M^2$, but equal in height on $M^3$; $M^2$ ectoloph deeply indented between $StB$ and $StD$; $M^3$ with well-developed anterobuccal cingulum, forming complete shelf with preprotocrista on $M^3$ but interrupted on other molars; $M^2$ usually lacks $StC$ but with distinct $StE$. $M^4$ narrower than $M^3$ and lacking metacone.

$I_1$, taller crowned than $I_{1-3}$, all with distinct posterior heel; $C_1$, twice the height of $P_2$ and with complete cingulum and associated anterior and posterior cuspules; $P_1$ and $P_2$ two-rooted with the primary cusp positioned above the anterior root; $P_3$ and $P_4$ with complete basal cingulum; $P_1$ usually lacking anterior cingular cuspule; $P_2$ with distinct anterior and posterior cingular cuspules; $P_3$, slightly taller and larger in crown area than $P_2$; $P_4$ absent; $P_5$ separated from $M_1$ by short diastema; $M_1$, paraconid reduced to small basal cuspule associated with buccal and lingual cingula; $M_1$ metaconid small to indistinct, positioned low on posterolingual flank of protoconid; $M_1$ lacking entoconid but with well developed postcingulid; $M_1$ to $M_4$ protoconid much taller than metaconid which is slightly taller than paraconid which is taller than hypoconid; $M_{2-3}$ with small but distinct entoconids which produce slight bulge in lingual margin of talonid; $M_{2-3}$ with well-developed postcingulids but precingulids and buccal cingulum poorly developed; $M_{2-3}$ with weak preparacristid spurs; $M_{2-3}$ cristid obliqua terminate well buccal to protocristid notch; $M_4$ trigonid similar to that of $M_{2-3}$ except narrower and shorter, but talonid greatly reduced, consisting of hypoconid and narrow talonid basin only; $M_4$, with weak buccal cingulum below cristid obliqua.

Pelage

Overall fur colour is reddish-brown dorsally and white ventrally. Hairs on back and shoulders are dark grey for basal half, topped with bright tan and bearing darker tips. Guard hairs are darker. Hairs on belly and chin are dark grey for basal third, topped with white. Face and cheeks with grizzled appearance. Hairs on face and cheeks pale tan with dark grey for basal third and at tips. Bright orange patch located behind ear. Hairs on upper surfaces of hands and feet white. Scrotum almost black with white hairs. Tail is distinctly bicoloured, hairs on upper surface tan, some with darker tips, usually paler to white below.

Pes

Pattern of pads is similar to the other species of *Pseudantechinus* (see Figure 11): terminal pads smooth; interdigital pads separate and clearly striated; hallucal and posthallucal pads and metatarsal granule clearly striated; plantar surface, including hallux, very granular; plantar surface hairless except for short hairs on medial side of heel.

Reproductive Anatomy

Females consistently have 6 teats in the well-defined pouch.

Males have an accessory penile process which is positioned ventral to, and is only slightly shorter than, the penis itself. The tip of the penis is weakly bifid and lacks a median dorsal lobe of the kind present in *Antechinus* spp.

Distribution

*Pseudantechinus roryi* is widespread through the northern Pilbara, north of the Hamersley Range and extending into the Great Sandy Desert as far east as Clutterbuck Hills (Figure 12). It also occurs on the Cape Range Peninsula. A population on Barrow Island probably represents *P. roryi*, although the few specimens in the Western Australian Museum are too damaged to be identified with certainty. *Pseudantechinus roryi* is sympatric over the southern and western part of its range with *P. ivooeyae*.

Interspecific comparisons

*Pseudantechinus roryi* can be distinguished from *P. macdonnellensis* of central Australia in being smaller.

Figure 11 Plantar pes of *P. roryi* sp. nov.
in most cranial measurements except for those related to bulla size (Table 2a) and in the following aspects of craniodental morphology: middle ear cavity more inflated in *P. roryi*, especially marked in case of posterior component (formed from rostral tympanic process of petrosal) which is more nearly comparable in size to alisphenoid portion; squamosal contacts frontal on lateral wall of braincase in higher population of cases in *P. roryi* (71% vs 56%; average separation in *P. macdonnellensis* is 0.93mm); I' and C' projecting further forward in *P. roryi* rather than slightly recurved; P' less markedly reduced in *P. roryi*; P' and P' cingula broken anteriorly and posteriorly in *P. roryi* rather than completely encircling crown; M' anterior cingulum is usually incomplete in *P. roryi*, with gap between anterobuccal cingulum and preprotocrista, rather than complete; M' lacks stylar cusp C in *P. roryi* rather than sometimes present; M' cingulum usually with low stylar cusp E in *P. roryi* rather than lacking that cusp; C, of *P. roryi* with complete basal cingulum linking anterior and posterior cingular cuspules, rather than with incomplete cingulum and only occasionally with anterior and posterior cuspules; P' cingulum and only occasionally with anterior and posterior cuspules; P' cingulum and only occasionally with anterior and posterior cuspules; P' cingulum and only occasionally with anterior and posterior cuspules; P_1, subequal in height and crown area in *P. roryi*, with primary cusps positioned more forward, closer to anterior root, rather than P_2, slightly higher and larger in crown area than P_1 and with more centrally primary cusps; P_1, also relatively narrower in *P. roryi*; P_2 anterior cingular cuspule only occasionally present in *P. roryi* rather than usually present; anterior end of P_2 contacts back of P_1, lingual to midpoints in *P. roryi* rather than centrally; M_1 with anterior portion of trigonid including paraconid reduced in *P. roryi*, resulting in shortening of trigonid relative to talonid; buccal cingulum on M_1 complete in *P. roryi* rather than incomplete; M_2 of *P. roryi* with cristid obliqua straighter and contacting posterior surface of trigonid in a more buccal position, rather than concave buccally and shifted lingually; M_2 of *P. roryi* with relatively broader postcingulids which continue around base of hypoconid rather than terminating on posterior surface of hypoconid; and

![Figure 12](image-url)  
*Figure 12* Localities of *Pseudantechinus* spp measured in this study.
M<sub>3</sub> entoconids less reduced in *P. roryi*, usually larger on M<sub>1</sub> than on M<sub>2</sub> rather than larger on M<sub>2</sub>. Externally, all species of *Pseudantechinus* are very similar in pelage colour and pattern, with the variation within species encompassing that seen between species. The major variation is in the redness of the dorsal hair, the percentage of grey in the basal part of the ventral and dorsal hair, the shade of grey in the dorsal and ventral hair and the degree of differentiation of the dorsal and ventral colour of the tail. All species have a flash of orange behind the ears. External differences are mainly in the ratio of the tail to head + body (snout-vent) length. The pattern of footpads is essentially the same in all species (Figure 11).

*Pseudantechinus roryi* differs from *P. macdonnellensis* in being smaller in all external measurements except SV; and having smaller external ears. The scrotum of *P. roryi* is wider and longer than that of *P. macdonnellensis* (scrotal width: mean = 13.2, range = 11.6-14.9, n = 8 vs 11.4, 10.3–13.9, 8; scrotal length: mean = 12.1, range = 7.9–13.9, n = 8 vs 10.1, 8.7-13.8, 8. A t-test comparing the scrotal widths and lengths between the two species indicated that scrotal width was significant at 0.001 (T=3.75) but there was no significant difference in length of scrotum. The sample of *P. roryi* was collected between May and August and the *P. macdonnellensis* sample between February and August. Woolley (1991) found that wild-caught *P. macdonnellensis* from Abydos and Woodstock produced young later in the year (births in October) than animals from central Australia (births in August to early September). Three females collected at Woodstock Station in October–November 1990 (How et al., 1990) were all carrying pouch young.

*Pseudantechinus roryi* differs from the widely sympatric *P. woolleyae* in being smaller in all external measurements and all craniodental measurements except for EW. It also differs in numerous aspects of craniodental morphology; petrosal component of bulla less strongly inflated in *P. roryi*; muscular fossa on anterior root of zygomatic arch slightly better developed in *P. roryi*; petrosal component of bulla more strongly inflated in *P. roryi*; squamosal and frontal in *P. roryi* commonly in contact on side wall of braincase, rather than excluded by contact of alisphenoid and parietal; petrosal component of auditory bulla more strongly inflated in *P. roryi*; anterior root of zygomatic arch in *P. roryi* with distinct muscular fossa enclosed by dorsal flange, rather than distinct, poorly enclosed fossa; P<sup>1</sup> in *P. roryi* smaller in crown area than P<sup>1</sup>, rather than subequal; P<sup>3</sup> in *P. roryi* less reduced and bearing two roots, rather than tiny and single-rooted; P<sup>2</sup> subequal to P, in crown height and area in *P. roryi*, rather than larger than P<sup>2</sup>; M<sub>1</sub> metaconid in *P. roryi* more reduced in size and height in *P. roryi*; M<sub>3</sub> entoconids more reduced and precingulids narrower and less distinct in *P. roryi*.

Female *P. mimulus* have 6 teats in the pouch. Male *P. mimulus* appear to lack an accessory penile appendage and have a conspicuously smaller scrotum than *P. roryi*.

*Pseudantechinus roryi* is similar to *P. ningbing* of the Kimberley region in most external and craniodental measurements but differs from this species in the following craniodental features:
of series; $M'_1$ lacks stylar cusp B in $P. \text{roryi}$, rather than retaining distinct stylar cusp $B$; $M'_1$ protocone less markedly reduced in $P. \text{roryi}$; $P_1$ never present in $P. \text{roryi}$, rather than commonly present; $M'_1$ metaconid smaller and lower in $P. \text{roryi}$ and $M_1$ entoconid absent, rather than low but distinct; $M_{2,3}$ entoconids low but distinct in $P. \text{roryi}$, rather than absent, and $M_{2,3}$ precingulids less distinct.

Externally $Pseudantechinus \text{roryi}$ differs from $P. \text{bilarni}$ in having the tail generally shorter than the head + body. Female $P. \text{bilarni}$ have 6 teats in the pouch. Male $P. \text{bilarni}$ lack an accessory penile appendage and have a conspicuously smaller scrotum than $P. \text{roryi}$.

**Etymology**

After Rory Cooper, the son of one of the authors. Rory is Gaelic for red and $Pseudantechinus \text{roryi}$ is generally a brighter reddish-brown dorsally than the other species of $Pseudantechinus$.

**DISCUSSION**

**Recognition of Sibling Species**

We have argued that the false antechinus populations previously identified as $Pseudantechinus \text{macdonnellensis}$ are more appropriately divided into two closely-related but diagnosable species. In our view, true $Pseudantechinus \text{macdonnellensis}$ is found in the central Australian uplands, extending west to Yamama Hmsd, and north into the Tanami Desert. Its sibling, the newly described $Pseudantechinus \text{roryi}$, inhabits the Pilbara uplands, extending north and east into the Great Sandy and Gibson Deserts. Although the distributions of the two taxa appear to be allopatric, their ranges approach to within 140 km in the Gibson Desert, and further collecting in this little-studied region may yet find them in sympathy.

The two species are diagnosable using the allozyme data, although only weakly so, with a single fixed difference and one other near-fixed difference. Significantly however, the limited genetic sampling within each of the two taxa suggests a high degree of genetic uniformity across very large distances, with very low levels of allelic variation overall. Similar low levels of heterozygosity and genetic uniformity across large distances have been noted in previous electrophoretic studies of dasyurid marsupials (Baverstock et al., 1982, 1983, 1984; Dickman et al., 1988) and appear to be fairly characteristic of the group. Most importantly, a number of other sibling species show low levels of genetic divergence (ie less than 10% fixed differences) amongst dasyurids (Baverstock et al., 1982).

 Morphologically, the two taxa are readily distinguished by a range of contrasting craniodental features including the relative degree of inflation of the middle ear cavity, the relative size of the cheekteeth, and details of cranial and dental anatomy. These differences suggest likely ecological differences between the two taxa, although both are primarily confined to upland, rocky habitats or to local outcrops and breakaways within the sedimentary basin deserts. In contrast to these between-species differences, morphometric analysis has shown each of $P. \text{macdonnellensis}$ and $P. \text{roryi}$ to be morphologically uniform across their respective ranges, with no evidence of clinal intergradation. This is an important observation that adds further strength to our suggestion that the two populations be distinguished at species level.

In concluding this section, it should be noted that Cooper and Woolley (1983) earlier postulated from electrophoretic evidence that the Tanami Desert population of $P. \text{macdonnellensis}$ might represent a distinct race to those in Central Australia. Unfortunately, it has not been possible to locate voucher specimens for the Tanami population to examine the craniodental morphology of this population. Nevertheless, it can be noted that the reported genetic differentiation was limited to an allele frequency difference at the transferrin locus, a protein known for its unusually high rate of genetic variability.

**Broader Relationships and Classification of the False Antechinuses**

The process of describing $P. \text{roryi}$ has stimulated a re-examination of broader relationships among the false antechinuses and their relatives. The picture which emerges is one of considerable morphological and genetic diversity and complexity. In the remainder of this discussion, we will review the various lines of morphological and molecular evidence that collectively bear on the phylogeny and classification of this problematic group.

Craniodental variation within this group has been discussed by Tate (1947), Ride (1964), Archer (1976a, b, 1982) and Kitchener and Caputi (1988). Tate’s (1947) interpretation of craniodental variation among dasyurids was remarkably prescient. He clearly recognized that the affinities of the ‘false’ antechinuses lay with the larger dasyurines, rather than with the phascogalines, and he also appreciated the significant differences in craniodental morphology between $Pseudantechinus$ (for $\text{macdonnellensis}$ and $\text{minimus}$) and $Parantechinus \text{apicalis}$. His diagnosis of $Pseudantechinus$ emphasised the reduction of the last premolars; the enlargement of $1$; the flatness of the skull; the narrowness of the nasals; and the inflated character of the auditory bulla. This contrasted with the high cranium of $Parantechinus$; its broader nasals; and its unenlarged $1$. Tate’s diagnosis of Dasyurinae mentioned only the “progressive obsolescence of $p$"
A new species of false antechinus

(= P'). As a prime criterion for membership in the subfamily (Tate 1947: 136). Tate's phylogenetic tree of the Dasyuridae (1947: figure 1) placed *Pseudantecharinichus* as the sister lineage to a group consisting of *Myocicis*, *Dasycercus* and *Dasyuroidea*, with this group as a whole the sister lineage to *Dasyurus* (sensu lato); *Parantecharinichus* was placed as the sister genus to *Neophascogale*, with *Pseudantecharinichus* (both New Guinean endemics) as their closest relative.

Ride (1964) returned all of the 'false' antechinuses to the broadly-conceived genus *Antechinus*, and in so doing, dismantled Tate's phylogenetic vision. Archer (1976b) initially followed Ride's generic concepts. However, following publication of new information on genetics and penile anatomy, Archer (1982) not only reinstated Tate's genera but created a third, *Dasycercus*, for Ride's *rosauroidae*. Archer (1982) also formally resurrected Tate's concept of a dasyurine radiation including *Pseudantecharinichus*, *Parantecharinichus*, *Myocicis*, *Dasyurus* (sensu lato) and *Sarcophilus* but excluding *Neophascogale* and *Pseudantecharinichus*, which he placed in a separate subfamily. Kitchener and Caputi (1988) included a *Phascolosorex*, which he placed in a separate (sensu lato) and *Dasyurideae* including *Pseudantecharinichus*, a third, *Archer Dasykaluta*, for Ride's *Dasykaluta*, was placed as *Neophascogale*, the sister lineage to *Dasyurus* (sensu lato); *Parantecharinichus* was placed as the sister genus to *Neophascogale*, with *Pseudantecharinichus* (both New Guinean endemics) as their closest relative.

Tate's phylogenetic tree highlighted a number of new characters of cladistic analysis of the 'false' antechinuses but failed to discuss the implications of the inferred phylogeny for craniodental evolution in this group.

Our own comparative studies of the skull and teeth of dasyurines have confirmed many of the findings of these earlier studies, but have also highlighted a number of new characters of potential significance. As indicated in the generic diagnosis, *Pseudantecharinichus* differs from all other genera of Dasyurinae in the degree of flattening of the braincase; the minimal development of a sagittal crest; and reduction in size of the upper and lower canines. Dentally, the group is characterised by a series of trends or 'tendencies' (e.g., for reduction of *P* in advance of *P*; for reduction of *P*; for reduction of the preparacrista and stylar cusp B on *M*; for reduction of stylar cusps C and E and of the anterior cingulum on all upper molars; for reduction of the proto- and meta-conules, with narrowing of the protocone; for reduction of the paraconid and metaconid on *M*; and for reduction of the entoconid and shortening of the talonid on all lower molars. However, for each of these characters, a relatively un特殊ised condition is present in one or more species of *Pseudantecharinichus* (e.g., *M* stylar B distinct in *P. woolleyae* and *P. bilarni*; *P* unreduced in *P. bilarni*; *M* entoconids less reduced in *P. woolleyae* and *P. mimulus*), and it would seem inescapable that a great deal of parallel dental evolution has occurred within the group. Interestingly enough, many of these same features are also observed in other dasyurine genera, most notably in *Dasycercus* and *Dasyuroidea*, which apart from being larger, are remarkably close to some *Pseudantecharinichus* spp. in dental morphology.

Among the various other species of *Pseudantecharinichus*, *P. roryi* most closely resembles *P. macdonnellensis* and *P. ningbing* in craniodental morphology. These species alone show contact between the squamosal and frontal bones on the side wall of the cranium, either as the typical condition (*P. ningbing*) or in a high proportion of cases (e.g., *P. macdonnellensis* and *P. roryi*). They also share an extreme reduction of the metaconid on *M*; an unusual narrowing of the precingulids and reduction of the parastylid spur on *M*,; and a lingual restriction but broadening of the anterobuccal cingulum on *M*. Together with *P. mimulus*, these species also display extreme reduction of both upper and lower third premolars, with complete loss of the lower tooth. All of these characters are judged to be derived or apomorphic in the broader context of the dasyurid radiation (Archer 1976a, b).

Each of *P. woolleyae* and *P. bilarni* appear morphologically more isolated; the former on account of its combination of a relatively un特殊ised dentition (*P* only slightly reduced; *M* with distinct stylar cusp B; *P* retained; *M*, with less reduced entoconids) and a greatly enlarged auditory bulla; and the latter with several highly derived dental characteristics (*P* unreduced but *P* tiny or absent; *M* lacking entoconid; *M* talonid and *M* protocone extremely reduced) and a distinctive cranial form with an anteriorly flaring zygomatic arch and posteriorly flaring nasals.

As noted by Tate (1947), *Parantecharinichus apicalis* differs from *Pseudantecharinichus* spp. in having a high-vaulted braincase, broader nasals, and a small but distinct postorbital process. It also differs in having less extensive fenestration of the maxillary and palatine portions of palate; a lesser degree of inflation of the auditory bulla (especially of the petrosal component); a noticeable enlargement of *P*; a lesser degree of reduction of *M*, talonids and of *M*3 protoconules; and a more procumbent *P*. In most of these features, *P. apicalis* is significantly less specialised than *Pseudantecharinichus*; an exception is the unusual character of *P* enlargement which is shared with certain *Dasyurus* species (e.g., *D. hallucatus*, *D. geoffroi*). Tate (1947) suggested that *P. apicalis* might be related to *Neophascogale* based on the shared features of a striped appearance and unusually elongate claws. However, those species differ in numerous aspects of craniodental morphology (Archer 1976a, b) that far outweigh the few superficial similarities.

Information on the anatomy of the penis played a major role in the recent resurrection of Tate's concept of the 'false' antechinuses. Woolley and Webb (1977) reported the presence of an accessory penile appendage in various genera of dasyurids.
including *Dasyurus*, *Sarcophilus*, *Myoictis* and *Antechinus* (*sensu lato*). Later, Woolley (1982) demonstrated that the penis of all *Pseudantechinus* and *Parantechinus* species features an anterior expansion and elaboration of the corpus cavernosum. In some species this forms a distinct appendage, which is short and indistinct in *P. ningbing*, but elongate and conspicuous in *P. macdonnellensis* and *Parantechinus apicalis*. However, the accessory appendage of *P. apicalis* differs from the other species in internal structure and shows some similarities with the unadorned but internally complex penis of *P. bilarni*. Kitchener and Caputi (1988; data supplied by Woolley) reported that *P. woolleyae* possesses an accessory corpus cavernosum but lacks a distinct appendage. The species of *Dasykaluta*, *Dasyceurus* and *Dasyurus* lack any specialisation of the corpus cavernosum (Woolley, 1982, 1987), as does the species *halucatus* within *Dasyurus* (P. Woolley, personal communication). As reported in this paper, *P. roryi* has a conspicuous accessory appendage that is at least superficially similar to that of *P. macdonnellensis*, whereas *P. minimus* lacks any obvious accessory structure; these species have not been examined microscopically (P. Woolley, personal communication.).

The phylogenetic significance of this variation in penile anatomy is moot. Archer (1982) used the penile anatomy to support placement of *bilarni* and *apicalis* within *Parantechinus*. In so doing he emphasised Woolley's (1982) characterisation of the accessory corpus cavernosum of these particular taxa as 'trifid' rather than the more typical 'bifid' condition. However, the 'trifid' condition in both taxa would appear to be a consequence of broadening of the accessory corpus cavernosum, resulting in an enclosure of the paired corpus spongiosum veins. In *P. bilarni*, the accessory corpus cavernosum encircles these veins to reform as a single median lobe; this does not occur in *P. apicalis*, which therefore has a distinctive, three pronged corpus cavernosum. Unfortunately, much of the information needed to assess the significance of these penile characters is not yet available, especially as regards the internal structure of the accessory penile appendages in *Dasyurus* spp., *Sarcophilus harrisii* and *Myoictis* spp. However, in view of our conclusions regarding the craniodental evidence, we regard it as potentially significant that within *Pseudantechinus*, a distinct accessory penile appendage has to date been recorded only in *P. roryi*, *P. macdonnellensis* and *P. ningbing* (albeit small).

Various genetic and molecular studies have included at least some of the species under consideration here. Baverstock et al. (1982) reported a genetic distance of 41% Fixed Difference (FD) between *P. macdonnellensis* and *P. bilarni*, based on a sample of 32 presumptive loci. Cooper and Woolley (1983) reported a larger genetic distance (59% FD) between *P. macdonnellensis* and *P. bilarni* based on a smaller number of presumptive loci, and distances of 44% FD and 41% FD between each of these species and *P. ningbing*. An unpublished genetic study by M. Adams documented a genetic distance of 38% FD between *P. roryi* and *P. woolleyae* from Woodstock Station and 15% FD between *P. macdonnellensis* and *P. minimus*. These results also show *P. apicalis* to be at least 30% FD from all other members of the group including *P. bilarni*. These intrageneric distances are comparable to those which separate other genera of Dasyurinae (e.g., *Antechinus* vs *Phascogale*; *Ningaui* vs *Sminthopsis*; Baverstock et al., 1982), and thus provide no support for either the monophyly of *Pseudantechinus* or for the recognition of additional species-groups within this group.

DNA sequence studies by Krajewski et al. (1993, 1994, 1997) also point to considerable phylogenetic diversity among the assemblage of smaller dasyurine species. Their most recent analysis of combined Cytochrome b, 12S rRNA and Protamine P1 sequence data suggests monophyly of *Pseudantechinus roryi* (*as macdonnellensis*) and *P. woolleyae*, but show wide separation of these taxa from each of *bilarni* and *apicalis*. Of these latter taxa, *bilarni* is placed as a possible sister taxon to a large clade containing *Dasyurus*, *Sarcophilus*, *Phascolosorex* and *Neophascogale*, while *apicalis* is linked to *Dasykaluta rosamondae*, albeit with low bootstrap support. Incomplete sequence data for *P. ningbing* fails to show a special relationship with any of these taxa.

Taken at face value, the DNA sequence data appear to challenge our notion of a monophyletic *Pseudantechinus*. However, it is perhaps prudent at this point to note certain other discrepancies between the results of Krajewski et al. (1997) and some well-established notions of dasyurine phylogenetics; for example the basal separation in the Krajewski et al. dataset between *Dasyceurus* and *Dasyurus*, which on other genetic and DNA sequence data should probably be regarded as congeneric (Bavestock et al., 1982; Cooper and Adams, unpublished data). One possible explanation of such discrepancies is the presence in the Krajewski et al. dataset of one or more pseudogene sequences. Although the issue of pseudogenes (sometimes called nuclear paralogues) has been acknowledged for many years (Zhang and Hewitt, 1996), their ubiquitous nature and their preferential amplification in some tissues but not others has only recently become apparent (Greenwood and Paabo, 1999). Until such time as this possibility has been explored [several procedural methods are available; e.g., Keogh (1998)], we do not regard the published molecular phylogenetic perspective as carrying any special weight.

To attempt to stabilize taxonomic classifications
in the face of this largely contradictory and glaringly incomplete suite of evidence might seem premature. Nevertheless, we feel sufficiently confident to draw a number of conclusions regarding the phylogeny and classification of the smaller dasyurines. The first is that the degree of molecular and morphological diversity within the loose assemblage of false antechinuses more than justifies the current recognition of multiple genera, viz. Pseudantechinus, Parantechinus and Dasykaluta. Secondly, within this group, there seem to be strong morphological grounds (and some molecular genetic support) for recognising a core group within Pseudantechinus, comprising macdonnellensis, rorii, ningbing and mimulus. Thirdly, we are confident that each of apicalis and rosamondae are phylogenetically distant to the core Pseudantechinus cluster, and further, that each warrant generic distinction as Parantechinus and Dasykaluta respectively. This leaves us with two species, woolleyae and bilami, both of which share a number of derived craniodental features with the ‘core’ Pseudantechinus, but which appear to be each somewhat removed from the core group. In the case of woolleyae, this is mainly due to the retention of many plesiomorphic features, especially in the dentition. In contrast, bilami shows a more complex mosaic of plesiomorphic and autapomorphic features that make it phenetically distinct from all other false antechinuses. Nevertheless, we are quite confident that bilami does not have any special relationship with Parantechinus apicalis, as some workers have suggested.

The fundamental taxonomic problem is of course the perennial one of how best to classify cladinic ‘radicals’, whether basal ones, as in the case of woolleyae, or highly autapomorphic ones, as in bilami. Our suggested solution is to include both of these taxa within Pseudantechinus, with which they show the greatest overall phenetic similarity. However, in so doing, we admit the possibility that the genus Pseudantechinus is rendered paraphyletic with respect to other dasyurine genera including Dasycercus and Dasyuroidea.

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New records of the water mite family Hygrobatidae from Australia, with the description of ten new species (Acari: Hydrachnidia)

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Abstract – Five new Australiobates species are described, viz. A. crassisetus, A. hygrobatoideis, A. minutipalpis, A. planisetus and A. tenuisetus. Furthermore, three new Procorticacarus species are described, viz. P. fonticolus, P. mixtus and P. piriformis. Finally, one new Rhynchaustrobates species and one new Coaustraliobates species are described, viz. R. stylatus and C. rostratus. Kallimobates cooki is synonymized with K. australicus. The male of Hygrobates australicus and the females of Aspidiobates wittenoom and Condvoanabates bodivus are described for the first time. Australiobates convexipalpis is reported for the first time for Australia. Many new records are given for a number of species of the water mite family Hygrobatidae, especially for the Northern Territory and Western Australia. Finally, the diversity of the Australian water mites is briefly discussed.

INTRODUCTION

The water mite family Hygrobatidae is represented in Australia by 17 genera (Harvey, 1998), of which 14 are endemic to the Australian region (Australia, New Guinea, New Zealand and New Caledonia). The family occurs mainly in streams and hyporheic habitats, where some species can occur in large numbers, e.g. Kallimobates australicus K.O. Viets in streams in montane eastern Australia. In ponds and lakes Coaustraliobates minor (Lundblad) occurs in large numbers (this study).

In this paper the results are presented of collections made in Victoria, Tasmania, Northern Territory and Western Australia. New species are described for the genera Australiobates, Coaustraliobates, Procorticacarus and Rhynchaustrobates. In addition, many new records are given, including records new for the fauna of Australia, especially for the Northern Territory and Western Australia.

MATERIAL AND METHODS

All material has been collected by the author. Victorian holotypes and paratypes have been deposited in the Museum of Victoria, Melbourne (NMV), those of the Northern Territory in the Northern Territory Museum, Darwin (NTM). Holotypes and paratypes from Western Australia have been deposited in the Western Australian Museum, Perth (WAM). Furthermore, paratypes and all non-type material have been deposited in the Zoological Museum of the University of Amsterdam (ZMAN).

The following abbreviations have been used: PI = palp segment 1 (trochanter); IV-leg-4 = fourth segment of fourth leg (tibia of fourth leg); V4 = ventroglandularia 4. All measurements are in μm; measurements of leg and palp segments are of the dorsal margins. Measurements of paratypes in the description of new species are given in brackets. When the number of specimens reported in the literature is low, additional measurements are given.

SYSTEMATICS

Hygrobates Koch

Hygrobates Koch, 1837: 8.

Hygrobates australicus Cook

Figure 1


Material Examined

Australia: Northern Territory: 2 ♂, 3 ♀, Douglas River near Douglas Hot Springs, 1 August 1994.

Description

Male

Body 608–632 long and 478–518 wide. Chelicera 200 long, cheliceral claw 68 long. Genital field 170 in width and 130 in length; three pairs of acetabula (Figure 1). Dorsal lengths of PI-PV: 18, 74, 70, 134, 34; palp as in female. Dorsal lengths of I-leg-4-6:
Figure 1  *Hygrobates australicus*, genital field ♂. Scale line = 50 μm.

126, 142, 108. Dorsal lengths of IV-leg-4-6: 182, 190, 142.

Remarks
This is the first description of the male. The species is known from Queensland and Waigeo (New Guinea, Indonesia), and is reported here for the first time for the Northern Territory.

*Hygrobates hamatus* Vietts


Material Examined

Remarks
A widespread species, previously reported from Australia, Indonesia (including New Guinea), India and Sri Lanka. Gledhill and Wiles (1997) synonymized *H. h. bharatensis* with the nominate form. Within Australia, the species was known from Queensland, and is reported here for the first time for the Northern Territory and Western Australia.

*Australiobates* Lundblad


Remarks
The genus *Australiobates* has a typical Gondwanan distribution, occurring in all southern landmasses (Wiles, 1997a; Harvey, 1998). So far, there are 34 reported species, in two subgenera. From Australia 12 species are known, nine from New Guinea and five from New Zealand, all belonging to the subgenus *Australiobates*. The species from New Zealand (especially the males) are quite distinct, as they have an increased number of setae on PIII. Many species from New Guinea exhibit strong secondary sclerotization (Wiles, 1997a).

*Australiobates (Australiobates) crassisetus* sp. nov.

Material Examined
Holotype
♀, Lily Creek Lagoon, Kununurra, Western Australia, Australia, 17 September 1998 (WAM).

Paratypes
Australia: Western Australia: 1 ♀, same data as holotype (ZMAN); 1 ♀, Jack’s Waterhole (along Gibb River Road), The Kimberley, 14 September 1998 (WAM).

Diagnosis
Palp stocky, ventral margin of PIV with thickened setae.

Description
Female
Body 980 (1004–1085) long, 737 (729–818) wide. Suture line between third and fourth coxal plates complete or almost complete (Figure 2). Chelicerae not measurable; cheliceral claw 92 long. Three pairs of acetabula. One paratype with three acetabula on one side, and two on the other. Genital field 158 long and 194 wide. V4 posterior of genital field; V2 anterior of excretory pore. Lengths of PI-PIV: 30, 82, 74, 102, 41. Palp stocky, especially PIV. This last segment with one very thick seta on the ventral margin (Figure 3). Ventral margin of PIII convex, PIV with two long dorsodistal setae, which reach to posterior margin of PIV; ventral seta of PV blunt.
Figures 2–4  *Australiobates crassisetus*, holotype ♀: 2, ventral view; 3, palp; 4, I-leg-4-6. Scale lines = 200 μm (Figure 2), 50 μm (Figures 3–4).

Lengths of I-leg-4-6: 148, 150, 132; I-leg-5 ventrodistally with one blunt and one pointed seta (Figure 4). Lengths of IV-leg-4-6: 227, 251, 174. II-leg-5, III-leg-5 and IV-leg-5 with two swimming setae.

**Male**

Unknown.

**Remarks**

There are no other species which have a similar thick seta on the ventral margin of PIV. Moreover, all but one Australian species with swimming setae have a hair-like seta on the ventral margin of PIV.

**Etymology**

Named for the thickened setae on the ventral margin of PIV.

*Australiobates (Australiobates) convexipalpis* Wiles


**Material Examined**


**Remarks**

A species widely distributed in the lowland streams of New Guinea (Wiles, 1997a), reported here for the first time for Australia.

*Australiobates (Australiobates) hygrobatoides* sp. nov.

Figures 5–7

**Material Examined**

*Holotype*

♀, Glenisla River, at crossing with Red Rock Road, Grampians National Park, Victoria, Australia, 29 September 1997 (NMV).

**Diagnosis**

PIII convex, separation of capitulum and coxal plates indistinct, posterior process of capitulum very narrow.

**Description**

*Female*

Body 1012 long and 883 wide. Separation of capitulum and coxal plates indistinct. Posterior process of capitulum very narrow. Ventral part of capitulum covered with minute spines. Apodemes of fourth coxal plates short, ending just beyond posterior margin of fourth coxal plates (Figure 5). Genital field 223 long and 227 wide; anterior of acetabula a row of three setae. V4 anterior of genital field. Lengths of PI-PV: 44, 114, 110, 146, 46. Ventral margin of PIII convex, PIII with a relative short dorsodistal seta (Figure 6); ventral margin of PIV with a hair-like setae. Lengths of I-leg-4-6: 320, 308, 176; I-leg-5 with one pointed and one blunt seta (Figure 7). Lengths of IV-leg-4-6: 421, 454, 251; IV-leg-5 with a rudimentary swimming seta.
Figures 5-7  *Australiobates hygrobatoïdes*, holotype ♀: 5, ventral view; 6, palp; 7, I-leg-4-6. Scale lines = 200 μm (Figure 5), 50 μm (Figure 6), 100 μm (Figure 7).

**Male**

Unknown.

**Remarks**

No other *Australiobates* species has a similar palp, especially the shape of PIII is unusual for the genus. Moreover, all but one Australian species with a hair-like seta on the ventral margin of PIV have distinct swimming setae.

**Etymology**

The name refers to the resemblance of the new species to members of the genus *Hygrobates*, i.e. the indistinct separation of the capitulum and coxal plates.

*Australiobates (Australiobates) linderi* Lundblad


**Material Examined**


**Remarks**

The species has been reported from eastern and southern Australia. It is reported here for the first time for the Northern Territory and Western Australia. The species has a variable chaetotaxy of PIV and the legs. As pointed out earlier (Smit, 1992), the peg-like setae on the ventral margin are usually blunt, occasionally pointed. However, it seems that this character is dependent of the angle they are seen. The distance between these two setae is also variable, often they are located very close to each other. All specimens of this study have I-leg-5 with one blunt and one pointed setae, but occasionally more legs have blunt setae. I cannot find any differentiating characters, and assigned all to *A. linderi*. The best character by which to identify this species is the shape of PIII, which has a slightly
to distinctly bulging distal part, and the presence of hair-like, sometimes more thickened setae on the ventral margin.

Australiobates (Australiobates) minutipalpis sp. nov.
Figures 8–10

Material Examined

Holotype
♂, Barramundie Creek, Kakadu National Park, Northern Territory, Australia, 24 July 1994 (NTM).

Paratypes
Australia: Northern Territory: 2 ♂, 1 ♀, (NTM), 1 ♂, 1 ♀, same data as holotype (ZMAN).

Diagnosis

Palp very short, especially PIV and PV; PHI with long dorsodistal setae.

Description

Male

Body ventrally 429 long (405–417), dorsally 364 long (332–348), 275 wide (267–284). Suture line between third and fourth coxal plates incomplete. Posterior apodemes of fourth coxal plates long (Figure 8). Chelicera 157 long, cheliceral claw 46 long. Genital field 72 long and 92 wide. Three pairs of acetabula. V4 located anteriorly of genital field. Lengths of I-IV-PV: 16, 46, 58, 50, 18. Palp very short, especially PIV and PV. Setae on ventral margin of PIV peg-like; PIII with long dorsodistal setae (Figure 9). Lengths of I-leg-4-6: 80, 76, 66; I-leg-5 ventrodistally with short setae. Lengths of IV-leg-4-6: 142, 156, 116.

Female

Body 867 long and 672 wide. Posterior apodemes of fourth coxal plates long (Figure 10). Chelicere 258 long, cheliceral claw 70 long. Genital field 170 long and 160 wide. Three pairs of acetabula. V4

Figures 8–10
Australiobates minutipalpis, holotype ♂: 8, ventral view; 9, palp; 10, ventral view, paratype ♀. Scale lines = 200 μm (Figure 8–10), 50 μm (Figure 9).
located anteriorly of genital field. Lengths of PI-PV: 20, 76, 90, 80, 30; palp as in male. Lengths of I-leg-4-6: 126, 126, 104. Lengths of IV-leg-4-6: 198, 238, 170. IV-leg-5 with one rudimentary swimming seta.

Remarks
The very short palp, especially PIV and PV, is not found in any other species. Moreover, all other known species with enlarged dorsodistal setae of PII, have hair-like setae on the ventral margin of PIV.

Etymology
Named for its very short palp.

Australiobates (Australiobates) mutatus K.O. Viets

Material Examined
Australia: Tasmania: 2 δ, 1 9, unnamed creek 2.5 km off Tasman Highway, at crossing with Rosendale Road, Bicheno, 19 October 1997; 5 δ, 1 9, Douglas River at crossing with Tasman Highway, 20 October 1997. Victoria: 7 9, 3 δ, Glenelg River at crossing with Siphon Road, Grampians National Park, 29 September 1997; 9 9, 10 δ, Glenisla River at crossing with Red Rock Road, Grampians National Park, 29 September 1997; 1 9, Fyans Creek at crossing with Grampians Tourist Road, 30 September 1997; 4 δ, 2 9, Billimina Creek, Grampians National Park, 30 September 1997; 2 δ, 2 9, Mackenzie River at Zumst, Grampians National Park, 1 October 1997; 1 9, Ovens River at Wangaratta, 9 October 1997; 1 9, Running Jump Creek, Mt Buffalo National Park, 10 October 1997; 1 δ, 3 9, unnamed creek The Long Plain, Mt Buffalo National Park, 10 October 1997; 2 δ, 3 9, Buckland River at crossing with Buckland Valley Road, west of Bright, 11 October 1997; 1 9, Shipwreck Creek, Croajingolong National Park, 23 October 1997; 1 δ, Betka River at crossing with Stony Creek Road, south-west of Genoa, 24 October 1997. Northern Territory: 6 δ, 3 9, 3 nymphs, Barramundie Creek, Kakadu National Park, 24 July 1994; 20 δ, 19 9, 5 nymphs, South Alligator River, 11 km east of Gunlom, Kakadu National Park, Northern Territory, Australia, 26 July 1994 (NTM). Western Australia: 1 δ, 3 9, small stream near pool upstream of Bell Gorge Falls, The Kimberley, 11 September 1998.

Remarks
So far, the species was known from Tasmania to Queensland. These are the first records for the Northern Territory and Western Australia. As already mentioned by Cook (1986), there is a considerable variation in size. My largest female specimen (from Billimina Creek) is 1239 long and 1045 wide. This is much larger than the largest female of Cook (1986), which was 851 long. As all intermediate measurements can be found, and all are structurally similar, I consider all specimens to belong to one single species.

Australiobates (Australiobates) neolinderi Cook

Material Examined
Australia: Tasmania: 5 9, Nive River at crossing with Lyell Highway, 14 October 1997; 3δ, 6 9, Apsley River at crossing with Tasman Highway, 19 October 1997; 1 9, unnamed creek 2.5 km off Tasman Highway, at crossing with Rosendale Road, Bicheno, 19 October 1997.

Remarks
An endemic Tasmanian species.

Australiobates (Australiobates) planisetus sp. nov.

Material Examined
Holotype 9, South Alligator River, 11 km east of Gunlom, Kakadu National Park, Northern Territory, Australia, 26 July 1994 (NTM).

Paratype
Australia: Northern Territory: 1 9, same data as holotype (ZMAN).

Diagnosis
1-leg-5, II-leg-5 and III-leg-5 with enlarged, flattened setae; ventral margin of PIV with peg-like setae, which end distally with a bevelled edge.

Description
Female
Body 608 (559) long and 454 (425) wide. Suture lines of third and fourth coxal plates nearly complete. Apodemes of fourth coxal plates of moderate length (Figure 11). Genital field 142 long and 146 wide. Three pairs of acetabula, V4 located laterally of genital field. Dorsal lengths of PI-PV: 28,
New Hygrobatidae from Australia

Figures 11–13  *Australiobates planisetus*, holotype ♀: 11, ventral view; 12, palp; 13, I-leg-5-6. Scale lines = 200 µm (Figure 11), 50 µm (Figures 12, 13).

44, 67, 76, 26. PII dorsodistally with a long serrated seta, PIII with long dorsodistal setae. Ventral margin of PIV with peg-like setae, which end distally with a bevelled edge (Figure 12). Dorsal lengths of I-leg-4-6: 117, 126, 94. Dorsal lengths of IV-leg-4-6: 200, 224, 148; IV-leg-5 with two rudimentary swimming setae. I-leg-5, II-leg-5 and III-leg-5 with one enlarged, flattened seta and one pointed seta (Figure 13).

**Male**

Unknown.

Remarks

*Australiobates queenslandensis* has somewhat similar setae on the distal end of the first leg, although they are not as large as in the new species. However, *A. queenslandensis* has hair-like setae on the ventral margin of PIV, in the new species these setae are peg-like. *A. longiseta* Wiles from New Guinea has a similar palp with long dorsodistal seta of PIII, but PIV is stockier, and the dorsodistal setae of PIII are extending beyond the posterior margin of PIV.

**Etymology**

Named for the flattened setae of PIII.


**Material Examined**


Remarks

The species has previously been reported only
from Queensland. It is reported here for the first time from the Northern Territory and Western Australia. There is one character not mentioned by Cook (1986): V4 are located posteriorly of the genital field.

**Australiobates (Australiobates) rudagus** Cook


**Material Examined**


**Remarks**

This species has previously been described only from Queensland. Therefore, the new records from the Northern Territory and Western Australia represent a considerable range extension. My specimens have a slight to distinct convex PIII, which is not present in the specimens from Queensland. However, all have the distinctive heavy peg-like seta of the ventral margin of PIV. The largest female from this study measured 959 in length and 769 in width. V4 is located laterally of the genital field.

**Australiobates (Australiobates) tenuisetus** sp. nov.

**Material Examined**

*Holotype*

♂, South Alligator River, 11 km east of Gunlom, Kakadu National Park, Northern Territory, Australia, 26 July 1994 (NTM).

*Paratypes*

Australia: Northern Territory: 2 ♂ (NTM), 1 ♂ (ZMAN), same data as holotype; 2 ♂, Katherine River at visitors center, Katherine Gorge National Park, 28 July 1994 (ZMAN).

**Diagnosis**

PIII with long, thin dorsodistal setae; peg-like setae on ventral margin of PIV relatively thick.
New Hygrobatidae from Australia

Description

Male
Body dorsally 437 (429-478) long and ventrally 478 (486-522); width of body 364 (364-405). Suture lines between third and fourth coxal plates incomplete to almost complete (Figure 14). Posterior apodemes of fourth coxal plates relatively short. Genital plates with three pairs of acetabula; genital field with long setae. Lengths of PI-PV: 23, 86, 92, 114, 33. PIII with two setae on medial side, ventral margin without setae. PIII with two long, thin dorsodistal setae, reaching almost halfway PIV (Figure 15). Ventral margin of PIV with two thickened, peg-like setae, which are rounded apically. Lengths of I-leg-4-6: 148, 158, 118; dorsodistal setae of I-leg-5 of normal shape. Lengths of IV-leg-4-6: 219, 220, 162. Legs without swimming setae, only rudimentary setae are present.

Female
Unknown.

Remarks
Few other Indo-Australian Australiobates-species have a combination of peg-like setae on the ventral margin of PIV and long dorsodistal setae of PIII. The New Guinean A. longiseta Wiles and A. reticulata Wiles share this combination with the new species (Wiles, 1997a). PIV of A. longiseta is much stockier, and the dorsodistal seta of PIII extends beyond the posterior margin of PIV. A. reticulata has PIV with long, pointed peg-like setae, while the setae of the genital field are very short. The Australian A. rudagus Cook also has thickened peg-like setae on the ventral margin of IV, but these are much thicker. Moreover, A. rudagus has PIII with short dorsodistal seta.

Etymology
The species is named for its long, thin dorsodistal setae of PIII.

Australiobates (Australiobates) ventriscutatus

Cook

Australiobates ventriscutatus Cook, 1986: 90.

Material Examined
Australia: Western Australia: 1 ♂, pond Kalamina Gorge, near falls, Hamersley Range National Park, 13 August 1994.

Remarks
The species is widespread in eastern Australia, and has been reported from Tasmania, Victoria, New South Wales and Queensland. This is the first record from Western Australia, and represents a considerable range extension of the species.

Australiobates (Australiobates) violaceus

Lundblad


Material Examined

Remarks
There are some characters which are not mentioned by previous authors. I-leg-5 has one (rather short) swimming setae, II-leg-5, III-leg-5 and IV-leg-5 have two long swimming setae. Cook (1986) mentioned only the two swimming setae of IV-leg-5, but in two specimens from his collection examined by me, two swimming setae are present on legs II-III. The coxal plates of both males and females have a reticulate pattern. V4 located posteriorly of genital field. The largest male I collected is 931 long and 705 wide, the females are up to 1507 long and 1215 wide. These measurements are much larger compared with those of Cook (1986). The species has been reported previously from Tasmania, New South Wales and Queensland. The species is reported here for the first time for Victoria and the Northern Territory.

Coaustraliobates

Cook


Coaustraliobates (Coaustraliobates) longipalpis (Lundblad)

Material Examined
Australia: Western Australia: 1 ♀, pond Kalamina Gorge (near falls), Hamersley Range National Park, 13 August 1994.

Remarks
The species is known from Australia (Tasmania, Victoria) and New Guinea, and is reported here for the first time for Western Australia. C. longipalpis is much less common compared to C. minor.

Coaustraliobates minor (Lundblad)

Remarks
A widespread species, known from Australia, New Caledonia and New Guinea. Within Australia the species is common and reported from almost every state, but the species is reported here for the first time for Western Australia. Specimens with leg segments larger than the measurements given by Cook (1986) can be found. For males for example the following measurements were made for I-leg-4-6: 283, 332, 304 and for IV-leg-4-6: 421, 458, 397.

*Coaustraliobates rostratus* sp. nov.
Figures 16-17

Material Examined

**Holotype**
♀, Billimina Creek, Grampians National Park, Victoria, Australia, 30 September 1997 (NMV).

Diagnosis
The rostriform palp is diagnostic for the new species.

Description

**Female**
Body 802 long and 599 wide. Suture line of third and fourth coxal plates incomplete; coxoglandularia 4 located posteriorly of medial end of these suture lines. Apodemes of fourth coxal plates short (Figure 16). Genital field 146 long and 188 wide. Three pairs of acetabula. Dorsal lengths of PI-PV: 40, 74, 98, 195, 46. PIV very slender, contracted distally and therefore rostriform (Figure 17). Dorsal lengths of I-leg-4-6: 138, 154, 128. Dorsal lengths of IV-leg-4-6: 230, 258, 212. II-leg-5, III-leg-5 and IV-leg-5 with two swimming setae.

**Male**
Unknown.

Remarks
The unusual shape of the palp easily distinguishes the new species from the three known species of the genus.

Etymology
Named for its rostriform palp.

*Groonabates* Cook

*Groonabates stanopus* Cook


Figures 16-17 Coaustraliobates rostratus, holotype ♀: 16, ventral view; 17, palp. Scale lines = 100 μm (Figure 16), 50 μm (Figure 17).
Material Examined

Australia: Tasmania: 5♀, stream downstream of Russel Falls, Mt Field National Park, 17 October 1997; 2♀, unnamed creek at crossing with Rosendale Road, 2.5 km off Tasman Highway, Bicheno, 19 October 1997.

Remarks

Croonabates stanopus is endemic to Tasmania. Additional characters are the lineated integument and the slightly sinuous-shaped PIV.

\[ \text{Procorticacarus K.O. Viets} \]


Harvey (1998) and Cramer and Cook (1998) raised the subgenus Procorticacarus to the ranking of a full genus. So far, the genus has been reported from eastern and south-western Australia and New Guinea (Wiles, 1991, 1994; Harvey, 1998). In total, nine species are known from New Guinea and 18 species are known from Australia. In my collection there is one specimen from the Millstream-

\[ \text{Figures 18-22  Procorticacarus fonticolus: 18, dorsal view, holotype ♀; 19, ventral view, holotype ♀; 20, palp, holotype ♀; 21, ventral view, paratype ♂; 22, dorsal view, paratype ♂. Scale lines = 200 μm (Figures 18, 19), 50 μm (Figure 20), 100 μm (Figures 21, 22).} \]
Chichester National Park (Western Australia), far outside the known range of the genus. Unfortunately, the specimen is very young, and therefore not described here.

*Procorticacarus angulicoxalis* (K.O. Viets)


**Material Examined**
Australia: Victoria: 2 ♀, Ovens River at Wangaratta, 9 October 1997; 3 ♀, Ovens River at Porepunkah, 9 October 1997; 1 ♀, Eurobin Creek, at park entrance, Mt Buffalo National Park, 11 October 1997; 1 ♀, Buckland River at crossing with Buckland Valley Road, W of Bright, 11 October 1997.

**Remarks**
A widespread species, previously reported from Tasmania, Victoria and New South Wales (*Cook*, 1986).

*Procorticacarus fonticolus* sp. nov.
Figures 18–22

**Material Examined**

**Holotype**
♀, Ingleton Springs, Grampians National Park, Victoria, Australia, 30 September 1997 (NMV).

**Paratypes**
1 ♂ (young specimen, not well sclerotized), 3 ♀ (NMV), 3 ♀ (ZMAN), same data as holotype.

**Diagnosis**
Palp long and slender, female with two postocularia plates, male with one postocularia plate which is longer than wide; glandularia of fourth coxal plates of male located in the middle.

**Description**

**Male**
Body dorsally 359 long and 335 wide, ventrally 427 long. Integument with fine papillae arranged in a reticulate pattern, especially on postocularia plate. Postocularia plate longer than wide, somewhat rectangular in shape, but plate not well sclerotized and shape therefore difficult to ascertain (Figure 22); postocularia situated in the middle of plate. Glandularia plates of dorsum of moderate size. Capitular bay deep. First coxal plates fused. Glandularia on fourth coxal plates situated in the middle. Gland portion of coxoglandularia 2 absent. Three pairs of acetabula, posterior acetabulum separated by more than a diameter of an acetabulum from other two (Figure 21). Lengths of PI-PV: 26, 72, 114, 140, 60; palp as in female. Lengths of I-leg-4-6: 92, 106, 86. Lengths of IV-leg-4-6: 152, 156, 114.

**Female**
Body dorsally 575 (470-591) long and 494 wide, ventrally 624 long. Integument with fine papillae arranged in a reticulate pattern, especially on postocularia plates. Two postocularia plates present, 140 long and 96 wide (Figure 18). Glandularia plates of dorsum of moderate size. Capitular bay deep. First coxal plates fused. Gland portion of coxoglandularia 2 absent. Three pairs of acetabula (Figure 19). Lengths of PI-PV: 25, 88, 154, 189, 76; palp very long and slender (Figure 20). Ventral margin of PII with a large projection, tip covered with fine papillae; PIII ventrally with small papillae; PIV ventrally with a hyaline margin, peg-like setae inserted in this hyaline margin, proximal of the middle of this segment. Lengths of I-leg-4-6: 118, 110, 104. Lengths of IV-leg-4-6: 170, 186, 124.

**Remarks**
The new species is very close to *P. longipalpis* (*Cook*), which has a similar long and slender palp. However, the male of *P. longipalpis* has a postocularia plate which is wider than long, while the female has only one postocular plate. Moreover, the glandularia on the fourth coxal plates of the male are located near the posterior margin, while they are located in the middle in *P. fonticolus*. Other species which a similar slender palp differ in the number of acetabula or in the shape of PII.

**Etymology**
Named for its occurrence in a spring.

*Procorticacarus hirsutus* (K.O. Viets)


**Material Examined**

**Remarks**
A widespread species, known from Tasmania, Victoria and New South Wales.
Procorticacarus longipalpis (Cook)
Corticacarus (Procorticacarus) longipalpis Cook, 1986: 149.

Procorticacarus longipalpis (Cook): Harvey, 1998: 140.

Material Examined

Remarks
Previously only reported from Tasmania.

Procorticacarus mixtus sp. nov.
Figures 23-25

Material Examined

Holotype
♀, Shipwreck Creek, Mallacoota, Croajingolong National Park, Victoria, Australia, 23 October 1997 (NMV).

Diagnosis
Palp very slender; dorsum with two postocularia plates; first of four pairs of glandularia posteriorly of postocularia plates much further apart than second pair.

Description

Female
Body 640 long and 567 wide; dorsum 583 long. Integument with numerous fine papillae. Dorsum with two large postocularia plates (Figure 24), 144 long and 132 wide, postocularia located in the middle of plate; anterolateral corner of postocularia plates indented. First of four pairs of glandularia posteriorly of postocular plates much further apart than second pair. Capitular bay deep. Chelicera 252 long, cheliceral claw 61 long. First coxal plates separated medially; fourth coxal plates rounded medially. Genital field somewhat triangular, with 3 pairs of acetabula (Figure 23). Dorsal lengths of PI-PV: 32, 104, 167, 226, 70. Palp very slender especially PIV and PV; PIII ventrally with numerous papillae (Figure 25). PII with a large ventral projection, the top with fine papillae. Dorsal

Figures 23-25  Procorticacarus mixtus, holotype ♀: 23, ventral view; 24, dorsal view; 25, palp. Scale lines = 200 µm (Figures 23, 24), 50 µm (Figure 25).
lengths of I-leg-4-6: 134, 130, 96. Dorsal lengths of IV-leg-4-6: 182, 190, 140.

**Male**
Unknown.

**Remarks**
The configuration of the dorsal glandularia and the shape of the postocularia plates is similar to that of *P. australicus* K.O. Viets. However, the palp of the last species is rather stocky. Other species with a slender palp differ in having only one postocularia plate (*P. longipalpis*) or in different shaped postocularia plates and a different configuration of the dorsal glandularia (*P. fonticolus* sp. nov.).

**Etymology**
The name of the species refers to the combination of characters found also in other species.

### Procorticacarus pachydermis (Cook)
*Corticacarus (Procorticacarus) pachydermis* Cook, 1986: 144.

### Procorticacarus pachydermis (Cook): Harvey, 1998: 140.

**Material Examined**
Australia: Tasmania: 1 ♀, stream downstream of Russell Falls, Mt Field National Park, 17 October 1997. Victoria: 1 ♀, Ovens River at Porepunkah, 9 October 1997; 1 ♂, 1 ♀, West Kiewa River, 11 km upstream of Mount Beauty (near power station), 12 October 1997.

**Remarks**
Previously only reported from Tasmania. The specimens from Victoria have much larger acetabula compared to those of Tasmania. However, as discussed under *P. victorianus*, the acetabula size can be variable. Therefore, no new taxon has been described, and all specimens are assigned to *P. pachydermis*.

### Procorticacarus piriformis sp. nov.
Figures 26–28

**Material Examined**

**Holotype**
♀, Growler Creek, Wilsons Promontory National Park, Victoria, Australia, 27 October 1997 (NMV).

**Diagnosis**
Genital field with 6 pairs of acetabula. Dorsum with a large, pear-shaped postocularia plate.

**Description**

**Female**
Body 650 long and 601 wide. Integument with numerous fine papillae. Dorsum with a large pear-shaped postocularia plate, 432 long and 369 wide (Figure 27). Platelets associated with glandularia enlarged, gland openings slit-like. Capitular bay U-shaped, very deep. Chelicere 310 long. First coxal plates separated. Coxoglandularia 2 absent. Gonopore large, 136 long. Extensive secondary sclerotization posteriorly of fourth coxal plates. Six pairs of acetabula on an indistinct genital plate; medial three pairs separated from lateral three pairs (Figure 26). Lengths of PI-PV: 31, 118, 127, 204, 55. PII with a long ventral projection; ventral margin of PIII smooth; peg-like setae of ventral margin of PIV well separated, large and situated proximally (Figure 28). Dorsal length of I-leg-4: 104 (other segments lost). Dorsal lengths of IV-leg-4-6: 146, 154, 113.

**Male**
Unknown.

**Remarks**
All but one Indo-Australian members of the genus have less than four pairs of acetabula. Only *P. mcgratiae* (Wiles) from New Guinea has 4–6 pairs of acetabula, but differs from the new species in the configuration of the dorsal plates and glandularia platelets. The new species shares the slit-like gland openings with other species, e.g. *P. cooki* (Imamura) and *P. cramerae* (Cook).

**Etymology**
Named for its pear-shaped postocularia plate.

### Procorticacarus prasadi (Cook)
*Corticacarus (Procorticacarus) prasadi* Cook, 1986: 145.

### Procorticacarus prasadi (Cook): Harvey, 1998: 140.

**Material Examined**
Australia: Tasmania: 1 ♀, stream downstream of Russell Falls, Mt Field National Park, 17 October 1997.

**Remarks**
Only known from Tasmania.

### Procorticacarus victorianus (K.O. Viets)


Material Examined
Australia: Victoria: 5♀, Ovens River at Porepunkah, 9 October 1997; 4♂, Eurobin Creek, at park entrance, Mount Buffalo National Park, 11 October 1997.

Remarks
The acetabula of most of my specimens are much larger than illustrated by Viets (1978b). However, the size of the acetabula is variable and within some specimens a considerable variation can be found. The species has been reported from Victoria and New South Wales.

Dropursa Cook

Dropursa babinda Cook

Material Examined
Australia: Northern Territory: 1♀, 1 nymph, plunge pool Barramundie Creek, Kakadu National Park, 24 July 1994; 1♀, pools upstream of Waterfall Creek, Kakadu National Park, 25 July 1994; 1♂, plunge pool Gunlom Falls, Kakadu National Park, 25 July 1994; 1♂, 2♀, plunge pool

Figure 26-28
Procorticarus piriformis holotype ♀: 26, ventral view; 27, dorsal view; 28, palp. Scale lines = 200 μm (Figures 26, 27), 50 μm (Figure 28).
New Hygrobatidae from Australia


Remarks
The species has been reported previously from Tasmania and New South Wales. The new records from tropical North and North-west Australia represent therefore a considerable range extension. Unlike the two other known species of the genus, *D. boulloni* inhabits standing waters. Cook (1986) based his description of the female on one specimen only. Therefore, I will give some additional measurements: body 902–1380 long and 650–1056 wide; I-leg-5 407–485 long, I-leg-6 233–291 long.

*Aspidiobates* Lundblad

*Aspidiobates* Lundblad, 1941: 115.

*Aspidiobates scutatus* Lundblad


Material Examined
Australia: Victoria: 1 ♀, Eurobin Creek, at entrance Mt Buffalo National Park, 11 October 1997; 1 ♂, Croajingolong National Park, 23 October 1997; 1 ♂, 3 ♀, unnamed creek W of Secret Beach, Mallacoota, 23 October 1997.

Description
Male
Dorsal shield 553–626 long and 475–514 wide for males from Western Australia, 535–539 and 462 respectively for males from Northern Territory.

Female
Dorsal shield 679–728 long and 572–616 wide for females from Western Australia, 535–539 and 462 respectively for the females from Northern Territory.

Remarks
So far, the species is only known from the Pilbara region in Western Australia. The new records from Northern Territory are therefore a considerable range extension of the species. The type-locality ("Lily Pond/Crystal Pool") of the species is in the Millstream-Chichester National Park, and might be

*Aspidiobates geometricus* Cook


Material Examined
Australia: Victoria: 2 ♂, 4 ♀, Eurobin Creek, at entrance Mt Buffalo National Park, 11 October 1997.

Description

Remarks
Reported previously from New South Wales, Queensland and Victoria.

*Aspidiobates pilbara* Harvey


Material Examined

Description
Male
Dorsal shield 553–626 long and 475–514 wide for males from Western Australia, 535–539 and 462 respectively for males from Northern Territory.

Female
Dorsal shield 679–728 long and 572–616 wide for females from Western Australia, 559–648 and 474–543 respectively for the females from Northern Territory.

Remarks
So far, the species is only known from the Pilbara region in Western Australia. The new records from Northern Territory are therefore a considerable range extension of the species. The type-locality ("Lily Pond/Crystal Pool") of the species is in the Millstream-Chichester National Park, and might be
the same location as the Chinderwariner Pool. In a number of very young specimens (males as well as females) the dorsal shield is still undivided.

*Aspidiobates wittenoom* Harvey

*Figures 29–30*


**Material Examined**


**Description**

**Female**

Dorsal and ventral shields present. Dorsal shield 587 long and 485 wide. Dorsal shield with one large anterior platelet and four smaller posterior platelets (Figure 29). Large platelet 533, anterior small platelet 206 and posterior small platelet 202 in length. Large platelet with two pairs of glandularia, distance of posterior pair much larger than distance of anterior pair. Ventral shield 650 long and 572 wide. Genital field with four pairs of acetabula (Figure 30). Genital field 165 wide, gonopore 130 long. In the illustrated female one acetabulum is missing. Lengths of PI-PV: 22, 108, 90, 144, 44; palp as in male. Lengths of I-leg-4-6: 198, 202, 148. Lengths of IV-leg-4-6: 152, 140, 120.

**Remarks**

The female of the species had not previously been described. Harvey (1988) suspected *A. pilbara* and *A. wittenoom* to be sister-species, which can be confirmed now the female of *A. wittenoom* is known. The type-locality of *A. wittenoom*, which was the only known locality so far, is also in the Hamersley Range.

*Gondwanabates* Imamura

*Gondwanabates Imamura*, 1984: 64.

**Remarks**

So far, the genus *Gondwanabates* has only been reported from eastern Australia. The record presented in this paper is the first for the Northern Territory.

*Gondwanabates bodivus* Cook

*Figures 31–34*


**Material Examined**

Australia: Northern Territory: 2 ♀, South Alligator River, 11 km east of Gunlom, Kakadu National Park, 26 July 1994.

**Description**

**Female**

Dorsal and ventral shields present. Dorsal shield 407 (436) long and 252 wide. Anterior dorsal plate 216 (226) long, posterior dorsal plate 180 (175) long (Figure 31). Ventral shield 446 (475) long and 301 (301) wide. Capitulum, including anchoral process,
158 long; anchoral process relatively short. Genital field 112 wide, gonopore 84 long. Three pairs of acetabula (Figure 31). Lengths of PI-IV: 22, 82, 34, 70, 36; PIV with ventrally a ridge. Ventral margin of PII straight; PII with numerous small tubercles, PIII with fewer tubercles (Figure 33). Lengths of I-leg-4-6: 108, 116, 83 (Figure 34). Lengths of IV-leg-4-6: 116, 120, 100.

Remarks
Cook (1986) described only the male of *G. bodivus*. With the key provided by Cook (1986) the females are assigned to *G. bodivus*. The following combination of characters is diagnostic: posterior dorsal plates wider than long and with two pairs of glandularia, relative short anchoral process, palp of normal shape and I-leg-4 not enlarged. The species has previously been reported only from Queensland, so the new record represents a considerable range extension.

*Caenobates K.O. Viets*


*Caenobates acheronius K.O. Viets*

Material Examined

Description

Male
Dorsal shield 466 long and 359 wide. Ventral shield 572 long and 402 wide. Lengths of PII-PV: 72, 84, 80, 34. PII with short and broad distoventral projection; PIV with serrated ventral ridge, PIV relatively short.

Remarks
The male from the Northern Territory is smaller than the males from eastern Australia, and the ventral projection of PII is broader. According to Wiles (1997a) in the specimens from New Guinea the glandularia L4 and V4 are close together, lateral of the genital plate. In my specimen the two glandularia are closer compared to the eastern specimens, but not lateral of the genital plate.

Caenohales acheronius is known from Australia and New Guinea. Within Australia the species has been reported from Tasmania, Victoria, New South Wales and Queensland. The record presented here is the first for the Northern Territory, and fits well in the distribution pattern.

Kallimobates K.O. Viets


Kallimobates australicus K.O. Viets


Material Examined

Paratype of Kallimobates cooki Smit

Other Material

Description
Dorsal shield of male 495–621 long and 466–553 wide, of female 689–740 long and 592–650 wide.

Remarks
Cook (1986) stated that PII has only a slight ventral projection. This was the reason for me to describe K. cooki, which has a distinct projection on PII. However, it is clear that the shape of PIII is variable, and therefore K. cooki must be synonymized with K. australicus. Most of the females from this study have a distinct projection on PII. Imamura (1984) also pointed out this phenomenon. Moreover, closer examination of the paratype of K. cooki revealed, that the capitulum is similar to that of australicus.

K. australicus is known from Tasmania, Victoria, New South Wales and Queensland.

Kallimobates vietsi Cook


Material Examined
Australia: Victoria: 2 ♀, West Kiewa River, 11 km upstream of Mount Beauty, upstream of power station, 12 October 1997.

Description

Remarks
The species has previously been reported only from New South Wales and Victoria.

Rhynchaustrobates Cook

Rhynchaustrobates Cook, 1986: 123.

Rhynchaustrobates (Rhynchaustrobates) stylatus sp. nov.

Figures 35–36

Material Examined

Holotype
♀: MacKenzie River at Zumstein, Grampians National Park, Victoria, Australia, 1 October 1997 (NMV).

Paratype
Australia: Victoria: 1 ♀, same data as holotype (ZMAN).

Diagnosis
Extremely long cheliceral claw, four pairs of acetabula.
New Hygrobatidae from Australia

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Figures 35-36 Rhynchaustrobates stylatus, holotype ♂: 35, ventral view; 36, palp + capitulum. Scale lines = 200 μm (Figure 35), 50 μm (Figure 36).

Description

Female

Body dorsally 563 (538) long and 456 (446) wide, ventrally 621 (601) long. Idiosoma soft, lineated and without ventral shield. Glandularia of dorsum not in plates; postocularia on relatively small platelets. Capitular bay V-shaped. Capitulum attached to a long, protrusile tube. Coxal plates extending far beyond anterior body margin. First coxal plates fused. Posterior margin of fourth coxal plates triangular. Four pairs of acetabula, genital field crescent-shaped (Figure 35). Chelicera 295 long, cheliceral claw straight, 180 long. Lengths of PI-PV: 29, 70, 53, 84, 37; PIII without ventral projection (Figure 36). Lengths of I-leg-4-6: 96, 118, 98. Lengths of IV-leg-4-6: 132, 161, 144.

Remarks

The new species shares the number of acetabula with R. (Victoriabates) geometricus Cook. However, R. geometricus has a ventral shield (absent in the new species), and large dorsal plates (small in the new species). The only other Australian species with a large and straight chelicere is R. dividus Cook. This last species has three pairs of acetabula and the first coxal plates are separated. The finding of the new species implicates that the diagnosis of the typical subgenus must be amended: three or four pairs of acetabula present.

Etymology

Named for its long cheliceral claw.

THE DIVERSITY OF AUSTRALIAN WATER MITES

In his review on Australian water mites, Harvey (1998) reported 415 species of water mites. This is a relatively low number compared to Europe, with more than 900 species (Viets, 1978a), or to North America, where the number of species is estimated to be 1500 (Smith and Cook, 1991). However, Walter and Proctor (1998), in a study of water mites from tropical Australia, found that about 32% of the species they could compare with literature were undescribed. In the more tropical parts there were more undescribed species than in the more temperate parts. In the results published so far of my collections from northern and western Australia (Smit, 1996b, 1997, 1998a, 1998b, 1998c, present study), 69 species were identified, of which 42% were new to science. In my studies of water mites from eastern Australia (Smit, 1992, 1999, present study), only 22% of the species were new to science. This reflects the state of the art of Australian water mites, as most studies dealt with the eastern part of the country.

ACKNOWLEDGEMENTS

I am indebted to the Department of Conservation and Land Management (Perth), the Australian National Parks and Wildlife Service (Darwin), the Conservation Commission of the Northern Territory (Palmerston), the Natural Resources and Environment (Melbourne) and the Parks and Wildlife Service (Hobart) for their permission to collect water mites in the national parks, and Dr Walker (NMV) for the loan of material from the Cook collection. G.M. van der Pal assisted me with the field work, and J. Postma (Ann Arbor) corrected the English.

REFERENCES


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A new species of Cardinalfish in Neamia (Apogonidae, Perciformes) from Mauritius, Indian Ocean, with a review of Neamia octospina

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Abstract - Smith and Radcliffe described Neamia octospina in 1912. The genus was considered monotypic until a second species was discovered recently in the marine waters of Mauritius, Indian Ocean. Neamia notula sp. nov., differs from N. octospina in having 14 instead of 17-21 pectoral rays; eighth dorsal spine hidden by skin instead of visible, larger eyes, more slender body depth and an opercular spot instead of none. Neamia octospina, a widespread species, is reviewed. There is consistent variation in pectoral-fin ray counts between the Indian Ocean and West Pacific. There is no other morphological evidence to support recognition of more than one widespread species at this time.

INTRODUCTION

Smith and Radcliffe in Radcliffe (1912) based Neamia on a deeply notched dorsal fin with nine visible dorsal spines, ctenoid scales, villiform teeth in the jaws, no teeth on the palatines, a smooth preopercle margin and rounded fins. Neamia represents a derived apogonid genus with many modifications, and relationships with Apogonichthys, Fox, Fowleria, and Neamia have been hypothesized by Fraser (1972). All known species among these genera have rounded caudal fins, smooth preopercle ridge and edges, a single reduced supramaxilla, smooth posttemporals, low number of well developed gill rakers (5-9), and one pair of uroneurals. Table 1 provides a comparison of selected characters for these four genera.

No comprehensive review of the collections of Neamia has been made as part of any study. Klunzinger first described a species of Neamia in 1884 as Apogon sphemirus (suppressed) from the Red Sea. Smith and Radcliffe in Radcliffe, 1912, described Neamia octospina from the Philippine Islands. Smith (1955) first reported Neamia octospina from the Indian Ocean. Another species was described by Whitley in 1964 from Australia as Apogonichthys coggeri, but he missed the small, but visible, eighth spine in the dorsal fin. Gon (1987a) presented data that Klunzinger's use of the Apogon sphemirus name satisfies the Zoological Code but should be suppressed in favor of the more wide-spread use of Neamia octospina. He reported on two of the types and five West Indian Ocean specimens. An opinion suppressing this name was made in 1989 in the Bulletin of Zoological Nomenclature. Paxton et al. (1989) later synonymized Apogonichthys coggeri with Neamia octospina.

The discovery of a second species with a hidden eighth dorsal spine, an opercular spot, no palatine teeth, a completely pored lateral line and a body shape similar to Fowleria, at first suggested a new species in Apogonichthys. Examination of internal characters from x-ray photography revealed derived characters shared only with Neamia octospina. The purpose of this paper is to describe the new species and report on the variation and distribution of Neamia octospina.

Methods of taking and recording meristic data and measurements are given in Fraser and Lachner (1985). All measurements are in millimeters to the nearest 0.1. The following acronyms are used to designate institutions and collections cited and follow general usage given in Eschmeyer (1998): AMS Australian Museum, Sydney; ANSP Academy of Natural Sciences, Philadelphia; BPBM Bernice P. Bishop Museum, Honolulu; CAS California Academy of Sciences, San Francisco; HUJ Hebrew University, Jerusalem, Israel; ROM Royal Ontario Museum, Toronto, Canada; RUSI J.L.B. Smith Institute of Ichthyology, Grahamstown, South Africa; TAU Tel Aviv University, Israel; USNM collections of the former United States National Museum, deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C.; WAM Western Australian Museum, Perth, Western Australia; ZMB Universität Humboldt, Berlin, Germany. Field station numbers are listed for additional collection information, for example, VGS 69-23. Radiographs (x-ray) have been taken from type material of both species. These radiographs are in the possession of the first author.
Table 1  Comparison of selected characters for Neamia, Apogonichthys, Foa, and Fowleria.

<table>
<thead>
<tr>
<th>Character</th>
<th>Neamia</th>
<th>Apogonichthys</th>
<th>Foa</th>
<th>Fowleria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypural plate</td>
<td>1+2, 3+4 fused</td>
<td>1 to 4 free, or 1+2 fused</td>
<td>1 to 4 free</td>
<td>1 to 4 free</td>
</tr>
<tr>
<td>Urostylar centrum</td>
<td>3+4 hypurals fused</td>
<td>4th hypural fused</td>
<td>hypurals free</td>
<td>hypurals free</td>
</tr>
<tr>
<td>Uronerals</td>
<td>reduced or elongate</td>
<td>elongate</td>
<td>reduced</td>
<td>elongate</td>
</tr>
<tr>
<td>3rd epural</td>
<td>reduced or slender</td>
<td>hidden</td>
<td>elongate</td>
<td>elongate</td>
</tr>
<tr>
<td>Eighth dorsal spine</td>
<td>visible or hidden</td>
<td>1-2 rows</td>
<td>absent</td>
<td>in a band</td>
</tr>
<tr>
<td>Vomerine teeth</td>
<td>1-3 rows</td>
<td>none</td>
<td>none to a few</td>
<td>none</td>
</tr>
<tr>
<td>Palatine teeth</td>
<td>none</td>
<td>none to a few</td>
<td>none to a few</td>
<td>none</td>
</tr>
<tr>
<td>Ectopterygoid teeth</td>
<td>complete</td>
<td>complete</td>
<td>pits posteriorly</td>
<td>complete or pits posteriorly</td>
</tr>
<tr>
<td>Pored lateral line scales</td>
<td>absent</td>
<td>reduced</td>
<td>reduced</td>
<td>absent</td>
</tr>
<tr>
<td>Basisphenoid</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
</tr>
<tr>
<td>First pharyngobranchial</td>
<td>on 3rd</td>
<td>on 3rd</td>
<td>on 3rd</td>
<td>on 3rd, 4th, and 5th</td>
</tr>
</tbody>
</table>

SYSTEMATICS

Neamia Smith and Radcliffe in Radcliffe, 1912

Diagnosis
An apogonine with three hypurals, 1 and 2 fused, 3 and 4 fused, 5 free, hypurals 3+4 fused to urostylar centrum; one pair of reduced or slender uroncrural; three epurals; three supranurals; two supernumerary dorsal spines; smooth preopercle edges and ridge, smooth posttemporal; no basisphenoid; a reduced supramaxilla; no palatine teeth; lateral-line scales extending from posttemporal to base of caudal fin, all ctenoid with simple pores; rounded caudal fin; nine dorsal spines, eighth spine visible or hidden by skin, dorsal fin deeply notched and considered separate, the ninth spine at beginning of second dorsal fin; dorsal-fin rays 9; anal-fin rays 8; 14–21 pectoral rays; pale stomach, intestine and peritoneum.

Neamia notula sp. nov.
Figures 1a, 2; Table 2

Holotype
USNM 347045; (34.0 mm SL); Mauritius, Baie de la Petite Riviere, off Albion Fisheries Research Centre, Sta M-8, 24 m, 25 Apr 1995.

Paratypes
USNM 349188; (31.5 mm SL), taken with holotype, 1995. USNM 347044; (30.2 mm SL); Mauritius, La Preneuse, Black River Pass, Sta M-26, 34–36 m, 12 May 1995.

Comparative material
Fowleria sp. India: USNM 205215; 11(20-58 mm SL), Musal Tivu, Manauli Reef, LW-3, L. P. Woods, 20 Dec 1963. Fowleria flaminea USNM 345020; 6(26–37 mm SL), Papua New Guinea, Madang Harbour, 30 May, 1970, x-ray. Apogonichthys nafae Holotype USNM 62947; (22.1 mm SL), Japan, Naha, Okinawa I., x-ray. Apogonichthys marmorata Syntypes AMS I. 16311-001, formerly F 421; (34.9–39.6 mm SL), Australia, Cape Greenville, x-ray. Apogon auritus Holotype MNHN 8760; (54.4 mm SL), Mauritius. Apogonichthys polystigma Syntype RMNH 5611; (60.2 mm SL), Sumatra, Pratam. Apogon punctulatus Syntypes SMF 4685; (32.4 mm SL), Eritrea, Massaua, 1834. SMF 4686; (28.6 mm SL), same data as 4685. Apogon variatus Syntypes MNHN 1973-42; (25.7–

Figure 1  a, Holotype of Neamia notula, USNM 347045 from Mauritius, 34.0 mm standard length; b, Neamia octospina, USNM 26295 from Kranket I., New Guinea, 36.2 mm standard length; c, Neamia octospina, a fresh specimen from a color slide by J.T. Williams, USNM uncataloged from Useparapara, Tonga Islands, 36.2 mm standard length. Scale = 10.0 mm.
A new species of Cardinalfish

Figure 2 Distribution of the collection sites for *Neamia notula* ★ and *Neamia octospina* ● examined or cited from literature in this study.

33.5 mm SL), Madagascar, Nosy-Bé, x-ray. *Apogonichthys isostigma* Holotype USNM 51736; (50.3 mm SL), Samoa, Apia, x-ray.

**Diagnosis**

A species of *Neamia* with seven visible first-dorsal spines, spine 8 hidden by skin, darkish spot on the opercle below opercular spine with darkish blotch above, faint mark behind eye above the center line, body otherwise pale, 14 pectoral rays, four predorsal scales, eye diameter 12–13 % and body depth 35–40% of standard length.

**Description**

For general body shape see Figure 1a. Proportions measurements of holotype (in parentheses) and paratypes represented as % of standard length: greatest body depth 35–40 (40.0); head length 40–45 (42.6); eye diameter 12–13 (12.6); snout length 8.6–9.3 (9.1); bony interorbital width 4.4–6.0 (4.4); upper jaw length 20–22 (21.5); caudal peduncle depth 16–17 (16.8); caudal peduncle length 20–22 (20.0); first dorsal-fin spine length 2.6–3.5 (2.6); second dorsal-fin spine length 9.4–11 (9.4); third dorsal-fin spine length 19 (19.1); fourth dorsal-fin spine length 17–19 (17.3); spine in second dorsal fin 9.7–10 (9.7); first anal-fin spine length 2.0–3.3 (2.0); second anal-fin spine length 10 (10.0); pectoral fin length 23–24 (23.8); pelvic fin length 25 (24.7).

Dorsal fin VII-19, spine 8 hidden; anal fin II,8; pectoral fin 14-14; pelvic fin I,5; principal caudal rays 9+8; pored lateral line scales 23; transverse scale rows above lateral line 2; transverse scale rows below lateral line 6; median predorsal scales 4; circumpeduncular scale rows 12 (5+2+5). Total rudiments and gill rakers 13–14 (2+0–5+6–7), well developed gill rakers 0 upper arch, 5 lower arch.

Villiform teeth in a band of about five rows becoming two rows on side of premaxilla; villiform band of about five rows becoming two rows on side of dentary; one to three rows of villiform teeth on vomer; none on palatine, ectopterygoid, endopterygoid or basihyal.


Scales weakly ctenoid on body, cycloid on nape, opercle, cheek, interopercle and breast. Pored lateral-line scales simple, extending from posttemporal to base of caudal fin. Anterior nostril with a short tube, posterior nostril flat. Caudal fin rounded.

Life colours: Kuiter and Kozawa (1999) have the fresh-dead, with abdominal area distended, holotype of *Neamia notula* identified as *Fowleria aurita* (p. 51) from a photograph by P. C. Heemstra. Head and body reddish with blackish mark from ventral portion of eye becoming thicker along the posterior edge of eye onto nape; posterior nostril area blackish; blackish blotches on upper portion of
opercle and preopercle; semi-rounded blackish mark inside a pale, narrow edged area posteriorly and much wider anteriorly; base of pectoral fin with pale blotch; pale marks on reddish lips; iris mostly reddish, ventrally with partially yellowish semicircle; ventral portion of membrane between first, second and third dorsal spine blackish, rest of first dorsal fin light pinkish; second dorsal fin pale with an orange-reddish stripe near base of fin; caudal-fin membranes pale, fin rays orange-reddish; anal, pelvic and pectoral fins pale.

Colour in ethyl alcohol. Head and body pale, spot on opercle with a line of melanophores above centerline, five-six melanophores behind eye anterior to the top of the opercle. All fins pale, without any apparent marks or spots. Pale stomach, intestine and peritoneum.

Remarks

The new species shares a rounded caudal fin, smooth posttemporal edge, smooth preopercle edges and reduced supramaxilla with species of Apogonichthys, Foa, Fowleria and Neamia. Other selected characters for these genera are given in Table 1. The radiographs suggest the basisphenoid is reduced (no belophram portion, status of the meningost portion not possible) in the new species. The eighth dorsal spine is reduced, hidden by skin, unlike Neamia octospina, making N. notula similar to Apogonichthys in the sequence of reduction (clearly splitting the dorsal fin). Both Foa and Fowleria lack even the ossified evidence of the eighth spine (Fraser, 1972). Neamia notula shares with N. octospina the two fused hypural plates (1+2 and 3+4) and the fusion of hypural plate 3+4 to the urostylar centrum. Partial fusion of hypural plates 1 and 2 occurs in Foa fo (Fraser, 1972). Species of Apogonichthys have the fourth hypural plate fused to the terminal centrum. Foa and Fowleria have the basal pericard organization of five free hypurals. Neamia octospina has a reduced pair of uroneurals like Foa, while N. notula has a longer pair more like Apogonichthys and Fowleria. Information on the status of the first pharyngobranchial, shelves on the infraorbitalis and ceratohyal shape is unobtainable from the radiographs for the N. notula. All specimens of N. notula have the body shape somewhat distorted by expanded swimbladders. Nevertheless, this species has the general physiognomy of an Apogonichthys with a preserved color pattern similar to some Fowleria. Species of Foa and Fowleria have simple pored lateral-line scales from the posttemporal for up to 10–11 scales followed by one pit in each scale thereafter to the base of the caudal fin, while both Neamia and Apogonichthys have simple pored lateral-line scales complete from the posttemporal to the base of the caudal fin. No uniquely shared derived characters were identified for Neamia notula and species of either Foa or Fowleria. We place this species in Neamia because of the shared derived caudal skeleton characteristics not known in any Apogonichthys, Foa or Fowleria.

Neamia notula is known only from Mauritius in 24–36 m. Neamia octospina has been collected from stations as deep as 17–22 m., but has been most commonly collected in depths less than 6 m. This species differs from Neamia octospina in having the eighth dorsal spine hidden by skin, 14 pectoral rays instead of 17–21 (Table 2), 4 predorsal scales instead of 6, larger eye of 12–13% SL instead of 8.6–10% SL, more slender body of 35–40% SL instead of 40–45% SL and a darkish opercular spot instead of three marks radiating from the eye.

Specimens of Fowleria aurita and Fowleria rareigata were taken with Neamia notula. The opercular spot and the marking above it are similar to the opercular spot and markings found in these species of Fowleria, but both can be externally distinguished from the new species most easily by having posterior lateral line scales with a single pit in each scale instead of pored scales. One undescribed species, probably belonging in Fowleria, from the northern Indian Ocean has all lateral-line scales pored like Neamia.

Table 2 Frequency of the pectoral-fin ray counts for Neamia notula and Neamia octospina.

<table>
<thead>
<tr>
<th></th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
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<tbody>
<tr>
<td><strong>Neamia octospina</strong></td>
<td></td>
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<tr>
<td>Red Sea/ West &amp; Central Indian Ocean</td>
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<td></td>
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<td></td>
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<tr>
<td>Right</td>
<td>2</td>
<td>22</td>
<td>4</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>1</td>
<td>26</td>
<td>2</td>
<td></td>
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<td></td>
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<tr>
<td>Total</td>
<td>1</td>
<td>48</td>
<td>6</td>
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<tr>
<td>East Indian/ Pacific Ocean</td>
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<td>57</td>
<td>12</td>
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<tr>
<td>Total</td>
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<td>108</td>
<td>33</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td><strong>Neamia notula</strong></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>
A new species of Cardinalfish

**Etymology**

The species name, *notula*, is the diminutive of the feminine Latin noun *nota*, meaning mark, and refers to the spot on the opercle.

*Neamia octospina* Smith and Radcliffe in Radcliffe, 1912

Figures 1b, 1c, 2, Table 2

*Apopogon sphenurus* Klunzinger, 1884 [suppressed for purposes of priority by Commission on Zoological Nomenclature (Opinion 1564, 1989)].

*Apopionichthys coggeri* Whitley, 1964.

**Material Examined**


**Etymology**

The species name, *notula*, is the diminutive of the feminine Latin noun *nota*, meaning mark, and refers to the spot on the opercle.

*Neamia octospina* Smith and Radcliffe in Radcliffe, 1912

Figures 1b, 1c, 2, Table 2

*Apopogon sphenurus* Klunzinger, 1884 [suppressed for purposes of priority by Commission on Zoological Nomenclature (Opinion 1564, 1989)].

*Apopionichthys coggeri* Whitley, 1964.

**Material Examined**

Diagnosis

A *Neamia* with eighth dorsal spine visible, 17–21 pectoral-fin rays, 5–6 predorsal scales, body uniform or with faint markings on upper body scales, 3 brownish marks radiate from posterior portions of orbit, eye diameter 8.6–10% and body depth 40–45% of standard length.

Description

Range of proportions as % of standard length: greatest body depth 40–45; head length 40–45; eye diameter 8.6–10; snout length 7.6–8.8; bony interorbital width 5.8–6.6; upper-jaw length 21–24; caudal-peduncle depth 15–20; caudal-peduncle length 19–22; first dorsal-fin spine length 3.3–4.7; second dorsal-fin spine length 8.0–10; third dorsal-fin spine length 17–22; fourth dorsal-fin spine length 15–19; spine in second dorsal fin 8.7–10; first anal-fin spine length 3.5–5.4; second anal-fin spine length 11–13; pectoral fin length 31–35; pelvic fin length 26–29.

Dorsal fin VIII–1,9, deeply notched without membrane attaching the eighth spine to the ninth spine; anal fin II,8; pectoral fin 17–21, rarely 17 or 21 (Table 2); pelvic fin I,5; principal caudal rays 9 + 8; pored lateral-line scales 22–23; transverse scale rows above lateral line 2; transverse scale rows below lateral line 6–7; median predorsal scales 5–6; circumpeduncular scale rows 13 (5+2+6). Total gill rakers 13–16, 1–2 rudiments and 1–2 well developed on upper arch, 6–7 well-developed and 4–7 rudiments (plates) on lower arch.

Villiform teeth in band on premaxilla and dentary; two rows on vomer; none on palatine ectopterygoid, endopterygoid or basihyal.

Vertebrae 10+14. Three hyurpals (1+2 and 3+4 fused), one pair of reduced uroneurals, three epurals, third reduced, a free parhypural. Three supraneurals, two supernumerary spines on first dorsal pterygiophore. Basisphenoid absent. Supramaxilla present, reduced. Posttemporal smooth on posterior margin. Preopercle smooth on vertical and horizontal margins. Infradentary shelf present on third bone.


Live colours: From Smith (1961): "Alive, translucent pink much as in PI 46, F...". From Whitley (1964) – "Colour in life, pinkish yellow with white flanks and belly, slightly pellucid. Fins white to hyaline with brown spots along their bases. Pupil dark blue, iris silver with several pink and orange spots. Several brown marks, fringed by silver, radiate from eye." From Ida and Moyer (1974) – "The body and all the fins are transparent except for three radiating black lines from the eye." Kuiter and Kozawa (1999) have a live photograph of *Neamia octospina* by G. R. Allen as a tanish, semi-translucent fish with three radiating brownish lines from the eye. The colour transparency with ROM 65793 has the specimen with three reddish radiating lines from the eye, iris broken up into reddish and whitish areas, body reddish above and posterior to a whitish abdomen, upper and lower jaws whitish, pelvic and vertical fins with faint spotting on the spines and fin rays, but not on membranes.

Colour in alcohol: Colour in 70% ethyl alcohol. Body and fins pale without markings or scales with faint markings on upper body, fins pale or with faint spotting on fin rays, head with none to three faint eye marks posteriorly from the eye onto cheek, side of the head to posttemporal and onto anterior nape.

Habitat: Ida and Moyer (1974) reported their specimen was caught from a deep coral hollow.

Remarks

This species is known from the Red Sea to the West Pacific (Figure 2). It has been reported from the Maldives Islands (Gon, 1987a), from Taiwan.
A new species of Cardinalfish

(Shao and Chen, 1986) and from Ishigaki-jima, southern Japan (Ida and Moyer, 1974). Neamia octospina extends onto the Pacific Plate in the Carolina Islands chain at Pohnpei consistent with the discussion of other examples by Springer (1982, p. 124), but not elsewhere (Figure 2).

Whitley (1964) described a new species, Apogonichthys coggeri from Swain Reefs. He provided life color notes and noted that one specimen carried eggs in its mouth. He missed the small, visible eighth spine in the first dorsal fin of the holotype and paratypes. This type material has, in addition to eight first dorsal spines, no palatine teeth, pored lateral line scales from the posttemporal past the hyprunal plate, smooth preopercular edges and ridge, rounded caudal fin and 19-21 pectoral fin-rays. These characteristics along with the life and preserved color pattern are consistent with Neamia octospina. We agree with Paxton et al. (1989) that Apogonichthys coggeri is a junior synonym of Neamia octospina.

Variation in the number (4) of pectoral-fin rays is greater than observed variation within other species of cardinal fish. Usually, counts are invariant for most species and in some there are rarely a one or two fin-ray variation within a species. The western and central Indian Ocean and Red Sea material (west of and including Chagos Is.) tends to have 18 pectoral-fin rays while the Eastern Indian Ocean and West Pacific material (east of and including cocos Keeling Is.) tends to have 19 or 20 (Table 1). No other significant differences were identified. The largest specimen was 45 mm SL (western form) and 42 mm SL (eastern form). If new information reveals other differences, then the Red Sea-Western Indian Ocean form will require a new name. Neamia octospina has the highest pectoral-fin ray count of any known apogonid.

The small eye diameter may suggest that this species is active during the day.

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The earliest Cambrian Polyplacophorans from China

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Abstract - Restudy of Yunnanopleura, Tchangsichiton, Runnegarochiton, Meishucunchiton, Yangtzechiton and Luyanhaochiton from the earliest Cambrian in the Yangtze Region of China confirms the appearance of the Polyplacophora in the earliest Cambrian. It also suggests an origin for the class in late Proterozoic. Yangtzechiton and Luyanhaochiton, represented in the study material, are typical polyplacophorans having head, intermediate and tail valves, each with a tegmentum and an articulamentum. These morphologic features establish their distinction from the non-molluscan genus Paracarinachites. The polyplacophoran character of species of the genera Yunnanopleura, Tchangsichiton, Meishucunchiton and Gotlandochiton? is demonstrated by the presence of discrete areas (central or jugal, lateral) on the intermediate valves. Yunnanopleura is probably ancestral to the Early Ordovician Chelodes Davidson and King. Runnegarochiton appears to be closely related to the Middle Ordovician Priscochiton Dall.

INTRODUCTION

The Yangtze Region is one of the areas in China where the Lower Cambrian is most developed. It has been studied in great detail, with the location of type sections for series division and stages established. During the past 30 years, as a result of ongoing research on the Proterozoic-Cambrian boundary strata, a great number of molluscs have been discovered from the Meishucun Stage of eastern Yunnan, western Sichuan, western Hubei and southwestern Shaanxi. They are especially significant from the Meishucun section of Jinning and the Baizai section of Xundian, Yunnan (Figure 1).

The Meishucun Stage of the Yangtze Region is dominated by a micromolluscan fauna. The fauna contains a diversity of primitive forms of polyplacophorans, merismoconchs, bivalves, stenothecoids, rostroconchs, hyoliths, tergomyans, helcionellids and gastropods. Among these fossils, the appearance of primitive Polyplacophora in the pre-trilobite and pre-archaeocyathid stage is particularly significant (Figure 2).

The writer has described two polyplacophorans from the earliest Cambrian, Yangtzechiton elongatus Yu (1984a, plate 1, figures 1-7; Yu 1984b, text-figure 4a-e) and Luyanhaochiton spinus Yu (1984a, plate 1, figures 8, 9; Yu 1984b, text-figure 4f-g). In 1987, the writer reported further earliest Cambrian polyplacophorans, including Yunnanopleura bifornis Yu (1987b, plate 17, figures 1-8; plate 18, figures 1-9; text-figure 43), Tchangsichiton notabilis Yu (1987b, plate 4, figures 1-10; text-figure 33), Sinuconus clypeus Yu (1979, plate 1, figures 10-13; 1987b, plate 5, figures 1-11), Runnegarochiton modestus Yu (1987b, plate 6, figures 1-6; text-figures 13, 35), Meishucunchiton vulgaris Yu (1987b, plate 15, figures 4-10; text-figures 36, 37), Postestephaconus tenes Jiang (1980, plate 1, figures 10-13; Yu 1987b, plate 7, figures 1-11; text-figure 38), Stoliczkanus zuanges Jiang (1980, plate 1, figure 1; Yu 1987b, plate 5, figures 12-13; plate 6, figures 7-10; text-figure 39) and Gotlandochiton? minuscus Yu (1987b, plate 15, figures 1-3; plate 16, figures 1-8; text-figure 42). Smith and Hoare (1987: 3) listed Yangtzechiton elongatus Yu and Luyanhaochiton spinus Yu as representatives of the Early Cambrian Polyplacophora. Haszprunar (1988: 402) has pointed out, “It is argued that the fossil record of the Polyplacophora starts much later than that of the Conchifera. However, in the light of recent findings of tiny Polyplacophora from the lowest Cambrian (Yu, 1987), this argument must be abandoned”.

Some scholars have lumped Yangtzechiton and Luyanhaochiton under Paracarinachites (Kerber, 1988: 187). Qian and Bengtson (1989: 48) have stated: “We cannot accept Yu’s (1984a, 1984b, 1987) interpretation of Yangtzechiton and Luyanhaochiton as polyplacophorans. As shown below, both of these generic names are junior synonyms of Paracarinachites...”.

On the other hand, He and Xie (1989: 126) considered that Paracarinachites has a long plate with spines, possibly representing the dorsal shield
of an animal. It was their view that *Yangtzechiton* might be the shells of primitive animals belonging to the Polyplacophora. Salvini-Plawen (1990: 2) wrote: "Moreover, the Precambrian and Early Cambrian Placophora described by Yu (1987) from China were like-wise small (1.2 mm-5 mm) ...". Morris (1990: 76) clearly stated that the Meishucunian contains a rich fauna of chitons, equal to any locality today. Peel (1991: 5) stated: "During the last decade fused associations of minute sclerites have been described from the earliest Cambrian of China and interpreted as microchitons (Yu, 1987, 1990). These have been seized upon as the missing early polyplacophoran link in molluscan evolution (e.g. Haszprunar, 1988; Yu, 1990)".

In the same year, Conway Morris and Chen (1991: 384, plate 8; text-figure 10) agreed with Qian and Bengston's viewpoint. Runnegar (1996: 82) stated "the earliest known chitons are not *Runnegarochiton* and its associates but instead are species of *Matthevia* from the latest Cambrian of the United States".

The writer is firmly of the view that *Yangtzechiton* and its related genera belong to the Class Polyplacophora, and that the affinities of *Paracarinachites* remain to be clarified (Yu, 1987b, 1990, 1993, 1996). During the last few years, there have been some exciting contributions on Cambrian fossils. *Triplicatella diffusa* Conway Morris, 1990 from the Lower Cambrian Parara Limestone and Ajax Limestone of South Australia (Bengtson et al. 1990) was reinterpreted as the earliest known polyplacophoran by Yates, Gowlett-Holmes and McHenry (1993: 71). Chen et al. (1995) recognized *Yunnanozoon lividum* Hou, Ramskold and Bergström, 1991 as the oldest chordate recorded from the Maotianshan Shale Member of the Lower Cambrian Yu'anshan Formation of Chengjiang, Yunnan, China (Chen et al., 1995).

There has also been new work on the Precambrian. Molecular test results of Wray et al. (1996) suggested that invertebrates including echinoderms, arthropods, anelids and molluscs diverged from chordates about a billion years ago, about twice as long as the Phanerozoic. One of the non-mineralized Ediacaran fossils, *Kimberella quadrata* (Glaessner and Wade 1966), from the Ust'-Pinega Formation of the Winter Coast of the White Sea in northern Russia, was reinterpreted by Fedonkin and Waggner (1997) as a mollusc-like fossil. Zhang et al. (1998) indicated that permineralized fossils from the terminal Proterozoic Doushantuo Formation of South China, including the large animals, radiated into a world rich in prokaryotic, protistan and even multicellular diversity which existed just before the Ediacaran radiation. The origin of shelled chitons within the late Proterozoic is in accord with the likely
Figure 2  Sketch map showing possible occurrence position of the three earliest Cambrian biotas (with the Meishucun section, Kunyang phosphorite mine, Yunnan, reproduced from Brasier et al. (1990) and revised by the writer).
evolutionary history of the Phylum Mollusca.

Early Cambrian Yangtzechiton and related genera possess some peculiar structures and they bear a very close evolutionary relationship to younger chitons.

What has been mentioned above indicates that polyplacophorans had already begun to diversify by the beginning of the Early Cambrian. However, Qian and Bengtson placed these polyplacophorans in synonymy with other small shelly fossils, and they are jumbled together with their taxa (Qian and Bengtson, 1989, 1992a, b; Qian, 1989, 1993). The aim of this paper is to discuss how to distinguish early polyplacophorans from other small shelly fossils in the earliest Cambrian.

Illustrated specimens are housed in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, People’s Republic of China.

WHY YANGTZECHITON AND RELATED GENERA ARE POLYPLACOPHORANS

Qian and Bengtson (1989: 49) concluded that there is no basis for the claim to polyplacophoran affinities of ‘Yangtzechiton’ or ‘Luyanhaochiton’, and that both are synonyms of Paracarinachites. The present writer finds Qian and Bengtson’s conclusion to be incorrect for the following reasons:

The polyplacophorans, or chitons, generally have a series of eight overlapping plates or valves, situated dorsally, and held in place by a tough muscular girdle, which may be either naked or variously ornamented with spicules, scales, bristles, or hairy protuberances (Smith, 1960). In Yangtzechiton elongatus Yu, the holotype comprises a head valve and two intermediate valves (Yu, 1984a, plate 1, figures 1–5; 1987a, plate 1, figures 1–4; 1987b, plate 8, figures 1–4, plate 9, figures 1–3, plates 10–12; 1990, plate 2, figures 1–3, plate 3, figures 1–5; 1993, plate 1, figures 1–2; Figures 3A–F): the paratype is composed of four intermediate valves and one tail valve (Yu, 1984a, plate 1, figures 6–7; 1987b, plate 8, figures 5–7, plate 14, figures 1–4; 1990, plate 2, figures 4–5; 1993, plate 1, figures 3–4; Figure 4A–B), and the third figured specimen has two intermediate valves (Yu, 1987a, plate 1, figure 5; 1987b, plate 9 figure 4; Figure 4C). In the other specimens there are six overlapping valves (Qian and Bengtson, 1989, figure 29A; Qian, 1993, plate II, figure A; Figure 5). In Luyanhaochiton spinus Yu, the holotype is composed of a head valve and three intermediate valves (Yu, 1984a, plate 1, figures 8–9; 1987a, plate 1, figures 6–7; 1987b, plate 13, figures 1–5, plate 14, figures 5–6; 1990, plate 2, figures 6–8; 1993, plate 1, figures 5–6; Figure 4D–E) and the figured specimen has two intermediate valves (Yu, 1987a, plate 1, figure 8; 1987b, plate 13, figure 6). So far as I know, no other chitons with such well preserved shells have been recorded from the Cambrian. The earliest hitherto fossil polyplacophorans remains (generally separate valves) occur in the Upper Cambrian and have been found sparingly in rocks of all geological ages (Smith, 1960). In most, the full complement of head, intermediate, and tail valves has not been found (Smith and Hoare, 1987).

The shells of polyplacophorans are generally 25–75 mm in length and occasionally up to 43 cm in the largest one known. However, the shells of those discovered from the earliest Cambrian of the Yangtze Region are only 3–5 mm in length, and just over 5 mm in the largest one. Although these primitive chitons are very tiny, they possess the basic features of the Class Polyplacophora. Smith (1960) indicated that head and tail valves usually differ in shape from each other and from the six intermediate valves, the latter commonly being much alike in contour. Like modern chitons, the shell of Yangtzechiton elongatus is composed of three different shapes of valves: the head valve is nearly as long as wide, without a raised hole (Figure 3A–B), anterior margin broadly rounded, posterior margin with a broad and deep sinus; the intermediate valve is longer than wide, with one-half of the valve overlapped by the preceding one, the middle of the anterior part has an elliptical hole, which may be the result of a hollow spine falling.
Valve is much wider than long, the anterior margin rectangular, with subcentrally located mucro off; and the tail valve is long and arched, very close evolutionary relationship to younger taxa. Yunnanopleura having a long valve and an apical hole, probably gave rise to Chelodes Davidson and King (1874), frequently found from the Early Ordovician (Bergenhayn, 1960; Runnegar et al., 1979) to Silurian (Figure 6D-F). Meishucunchiton is similar to Eochilon Smith (1964) from the Lower Ordovician of southern Oklahoma; Runnegarochiton is closely related to Priscochiton Dall (1822) from the Middle Ordovician of Canada in the outline of the intermediate valve and in the presence of a recurved tegmentum (Figure 6J-L). Yangtzechiton bears some resemblance to the genus Glyptochiton de Koninck (1883) from the Lower Carboniferous of Belgium (Figure 6P-Q), in the possession of a broad sinus at the posterior margin of the head valve, the intermediate valves are longer than wide and bearing a concave hole, though they are rather far from each other in geological age. Luyanhaochiton is analogous to the chitons of the later Paleozoic in the morphology of the shell, but in this genus, the anterior end of the intermediate valve is possessed of an obliquely backwardly directed hollow spine which makes it different from other known genera. Finally, Gotlandochiton? mininimus Yu is similar to Gotlandochiton troedssoni Bergenhayn from the Silurian of Sweden (Bergenhayn, 1955, plate I, figure 9; plate II, figure 7; Figure 6N).

These examples demonstrate that Yangtzechiton and related genera not only represent primitive forms of the major polyplacophoran groups that evolved after the Early Cambrian, but they also represent the initial diversification of the Class Polyplacophora. This discussion on the evolutionary relationships of polyplacophorans further confirms that C.R. Stasek's prediction has been realised in the Chinese fossil collections: “The

![Figure 4](image-url)
A COMPARATIVE STUDY OF YANGTZECHITON YU AND PARACARINACHITES QIAN AND JIANG

Comparisons were made between a great number of samples (more than five hundred specimens) were collected by the writer and his colleagues from the Baizai section in Xundian and the Meishucun section in Jinning, Yunnan in 1980. On the 11th June, 1981, the writer picked for the first time from an acid-residual sample, an earliest Cambrian polyplacophoran with the head valve and intermediate valves overlapping together. This came from the Lower Cambrian Zhongyicun Member of Tongying Formation of the Meishucun section of Jinning. The writer gave this information to Liu Di-rong and Qian Yi and introduced to them the locality, horizon and the morphological features of the Lower Cambrian Polyplacophora, as well as outlining the essential significance of the research on these fossils.

In 1984, Qian published on the Lower Cambrian polyplacophorans Carinachites spinatus and Paracarinachites sinensis. However, Qian's published descriptions and illustrations of presumed Early Cambrian polyplacophorans were not molluscs; he mistakenly regarded Carinachites spinatus Qian (1977, 265, plate III, figures 17-19) and Paracarinachites sinensis Qian and Jiang 1982 (in Luo et al., 1982: 183, plate 17, figure 17) as members of the Class Polyplacophora (Qian, 1984a: 93, plate I, figures 26-28; plate II, figures 14-16, 23-24; 1984b: 18, figures 1, 37-1, 38).

As previously noted (Yu, 1987b, 1990, 1993), the shell of Yangtzechiton elongatus is composed of a head, intermediate and tail valves. The intermediate valves consist of tegmentum and articulamentum, longer than wide, with one-half of the valve overlapped by the preceding one, and with an elliptical hole in the middle of anterior part, while Paracarinachites is an elongately curved sclerite, the whole composed of many thin lamellae arranged parallel to each other, and with 15-20 nodular projections and spines alternately arranged on the outer side.

The description of Paracarinachites sinensis (Qian and Bengtson, 1989: 49) centres around the sclerite formed by growth increments overlapping each other on the inner surface towards the abapical end. From the description and illustrations in He and Xie (1989, plate 1, figures 11-12); Qian and Bengtson, (1989, figures 27-28), and Yu (1993, plate 1, figures 10-11), it is clear that P. sinensis is composed of many thin lamellae arranged parallel to each other.

Along the middle of the dorsal surface of chitons, there extends a longitudinal series of eight, usually overlapping valves (Hyman, 1967). Overlapping refers, in particular, to the form of the shell in the Polyplacophora. In general, the posterior valve is usually overlapped by the preceding one. Sclerites, on the other hand, have been described by Qian and Bengtson (1989, 51): “The sclerites have a clearly laminated structure (Figure 27A3), suggesting that they are built up of superimposed

![Figure 5](image-url)
Earliest Cambrian Polyplacophorans


growth layers. The apical end of several specimens has a characteristic build-up of laminae (Figure 28) that also appear to represent successive growth increments. In fact, *P. sinensis* is built-up of six or more parallel arranged lamellae (Qian and Bengston, 1989, figure 28; Figures 4L–M, 7B–C). Therefore, the present writer concludes that these authors have not distinguished between the meaning of the words ‘overlapped’ and ‘superimposed’.

In *Yangtzechiton elongatus*, the ventral side of the head valve has a nephroid depression near the anterior margin, with a series of W-shaped curved striae in the posterior part of the depression; the intermediate valves are slightly concave on the ventral side, with contiguous fissures between individual valves clearly visible (Yu, 1984a, plate 1, figure 3; 1987a, plate 1, figure 2; 1987b, plate 8, figure 2; 1990, plate 2, figure 2; 1993, plate 1, figure 2; Figure 3D–E). In *Paracarinichites sinensis*, the lower side of the sclerite is divided into two parts: the adapical curved part with a subcircular dish bearing an opening in its subcentre, and posterior part widely concave (Qian, 1984a, plate I, figure 27; Yu, 1993, plate I, figures 8–9, 12–14; Figure 3l, 4N–P).

The number and arrangement of the spines or denticles also serve to distinguish between *Yangtzechiton* and *Paracarinichites*. In *Yangtzechiton elongatus*, the head valve is small, without a raised
Figure 7 A-C. Paracarinachites sinensis Qian and Jiang, A. Lateral view, x 30, NIGP 70939 (after Qian, 1984a). B-C. Lateral and ventral views, x 60, NIGP 106886 (after Qian and Bengtson, 1989). D. Paracarinachites bispinostis He and Xie, dorsal view, x 37.5, NIGP 106896 (after Qian and Bengtson, 1989).

has a raised hole, which may be the result of a hollow spine falling off (Yu, 1984a, plate 1, figures 1, 4, 6-7; 1987a, plate 1, figures 1, 3, 5; Figure 3A-B; 4A-C), while in P. senensis, the outer surface of the sclerite bears 5-6 nodular projections in the adapical curved part and 10-15 alternately arranged spines in the posterior part (Yu, 1987b, 1990, 1993; He and Xie, 1989; Figure 3G-H, 4F-K). But Qian and Bengtson (1989: 51) considered that "The largest number of denticles observed is 10". In their illustration the denticles usually number 10 or less, due to the incomplete specimens. However, years earlier Qian described a well-preserved specimen of P. sinensis, which has at least fifteen spines alternately arranged on the dorsal side (Qian, 1984a, plate 1, figure 28, NIGP 70939; Figure 7A).

In the diagnosis of the genus Paracarinachites, Qian and Bengtson (1989: 49) stated: "Outer surface with regularly spaced denticles, usually inclined towards the abapical end of the sclerite". The published illustrations of many specimens of P. sinensis (He and Xie, 1989, plate 1 figures 8-10; Qian and Bengtson, 1989, figure 27: Yu, 1993, plate 1, figures 7, 10, 15-18) clearly show the denticles alternately arranged on the dorsal side with their tips obliquely backward and inclined leftward (or rightward). In 1989, a new species Paracarinachites bispinostis He and Xie (1989, plate 1, figures 13-15) (=P. parabolicus Qian and Bengtson, 1989, figures 30-31) was described from the Lower Cambrian Dahai Member of the Tongying Formation of Huize, Yunnan. This species has two rows of spines on the dorsal side, their tips aligned obliquely leftward (or rightward) and backward (Figure 7D), similar to those of P. sinensis. These characteristics fully demonstrate that the diagnosis of the genus Paracarinachites and the description of P. sinensis provided by Qian and Bengtson (1989) does not fully reflect the precise features of the species, P. sinensis.

In this monograph, Qian and Bengtson claim that Yangtzechiton Yu and Luyanhochiton Yu, are both junior synonyms of Paracarinachites Qian and Jiang (Qian and Bengtson 1989: 48-54, 102-103). Conway Morris and Chen (1991: 382-385, 393-394), Bengtson (1992b: 408), Bengtson and Conway Morris (1992: 461, 467) and Qian (1989: 265; 1993) repeated the same view. From the above comparisons, it is clear that Yangtzechiton and Luyanhochiton are both valid taxa and that they belong to the Class Polyplacophora. Paracarinachites is no more than a single sclerite. The multivalved and univalved form is a major

Figure 8 A-G. Tchangischiton notabilus Yu, A. Dorsal view of an intermediate valve, showing the central and lateral areas and broadly U-shaped jugal sinus, x 65. B. Ventral view, showing the deep concave central area, x 80. Holotype. NIGP 84140. Coll. no. TF-1. C. Dorsal view of an intermediate valve, showing aesthetes, x 60. NIGP 84141. Coll. no. TF-1. D. Dorsal view, showing the sculptures, x 70. E. Ventral view, x 55. F. Posterior view, x 40. NIGP 84142 Coll. no. TF-1. G. Dorsal view of the tail valve, x 60. NIGP 84143. Coll. no. TF-1. Upper part of Huangshandong Member of Lower Cambrian Tongying Formation. Tianzhushan of Yichang, W. Hubei. H-N. Yunnanopleura biformis Yu, H. Dorsal view of an intermediate valve, showing the central and lateral areas (white arrow), x 30. I. Ventral view, showing the apical area with several rows of nodular projections, x 35. J. Left lateral view, showing the lateral and central areas (white arrow), x 35. K. Enlargement of the central and lateral areas, showing different kinds of the sculptures in the central and lateral areas, x 80. Holotype. NIGP 84173. Coll. no. XB-52. L. Left lateral view, showing lateral and central areas (white arrow), x 35. NIGP 84172 Coll. no. XL-52. M-N. Ventral views, showing the V-shaped apical area and other structures, x 30 and x 60. NIGP 84174. Coll. no. XB-52. Upper part of Zhongyicun Member of Lower Cambrian Tongying Formation. Baizai of Xundian, E. Yunnan. O-R. Poslestephanus tenter Jiang, O. Dorsal view of an intermediate valve, showing the central and lateral areas (white arrow), x 35. NIGP 84206. Coll. no. XB-28. Upper part of Zhongyicun Member of Lower Cambrian Tongying Formation, Baizai of Xundian, E. Yunnan. P. Right lateral view, x 85. Q. Dorsal view, showing bluntly rounded apex and lateral area (white arrow), x 90. R. Enlargement of apex and lateral areas x 180. NIGP 84209. Coll. no. KM-7. Upper part of Zhongyicun Member of Lower Cambrian Tongying Formation. Meshucun of Jinping, E. Yunnan.
character used in high level classification. Qian and Bengtson's treatment of *Yangzicheiton* and *Luyanhaochiton* as junior synonyms of *Paracarinachites*, is at variance with the basic concepts of biological taxonomy.

**ON THE DIFFERENCES BETWEEN OOCRURANUS LIU AND RUNNEGAROCHITON YU**

Qian and Bengtson (1989) discuss some other polyplacophorans from the Meishucun Stage, in which certain genera and species of the genus *Oocrurans* Liu are lumped together. However, before discussing the classification of these fossils, it is necessary to make clear the generic characteristic of *Oocrurans*. The genus was erected in 1979 by Liu, taking *Oocrurans finial* Liu as the type species (Liu, 1979, plate 1, figure 3; Figure 9D). The generic diagnosis given (Liu, 1979: 506) as follows: "Outline nearly conical; hinge line straight and wide; pseudointer area high, nearly procline; semiconical ventral and dorsal valves in rough mirror symmetry; ventral interarea procline, while dorsal one small, nearly catacline; homeodeltidium convex and well-developed, but with no foramen pedicle. Surface with concentric growth striates".

Liu (1987: 376–377) later supplemented the generic characteristics of *Oocrurans* as follows: "Shell small, slightly bilaterally asymmetrical, with semiconical ventral and dorsal valves in rough mirror symmetry; ventral interarea procline, while dorsal one small, nearly catacline; homeodeltidium convex and well-developed, but with no foramen seen; surface with only a small number of concentric bands; shell microstructure consisting of alternate sparse and dense thin layers of flakes". The amended generic diagnosis of *Oocrurans* is used for discussion of the problems with in Qian and Bengtson's taxa.

*Runnegarocliiton* Yu, 1987 is a polyplacophoran with *R. modestus* Yu as the type species. A comparison of *R. modestus* with the *Oocrurans finial* Liu shows their essential difference. In *R. modestus* (Yu, 1987b, plate 6, figures 1–6; Text-figures 13, 35; 1990, plate 1, figures 3–6; Figure 9A–C), the intermediate valve is subtringular in dorsal view; the tegmentum is recurved onto the ventro-posterior portion of the valve, forming a V-shaped hole below the apex, with its margin extending downward and then inversely curved outward, forming a recurved plate (Figure 9B–C). In *Oocrurans finial* (Liu, 1979, plate 1, figure 3; Figure 9D), the shell is subcicular, ventral valve semiconical, pseudointer area high and procline, pseudodelthyrium roundly-convex, but with no visible foramen; dorsal valve low-conical, apex rounded and slightly curved, situated posteriorly, interarea low (Liu, 1979: 506).

*Runnegarocliiton modestus* is also easily distinguished from *Oocrurans subpentaedrus* (Jiang) (1980: 117, plate 1, figures 6, 9, 14), because the shell of *O. subpentaedrus* is generally rounded to ovoid in outline and has a more or less straight proximal edge. The apex is situated close to the proximal margin. The subapical field is set off by a more or less pronounced furrow. A characteristic feature is the re-entrant at the proximal margin, which may form an acute angle and extend to the apex, or be less pronounced, resulting in a higher subapical field. The apical part together with the thickened rim of the subapical re-entrant are commonly preserved as isolated fragments (Qian and Bengtson, 1989: 106).
OTHER POLYPLACOPHORANS

As to the classification of *Stolicicus zonercs* Jiang (1980, plate 1, figure 2; Figure 10L-M) and *Postestephanocarps tentes* Jiang (1980, plate 1, figure 13; Figure 80-R) the problem is not as simple as Qian and Bengtson (1989: 103–106; Bengtson, 1992a: 416–417) suggested. It cannot be solved by attributing these taxa respectively to the species *Ocrurus finial* Liu and O. *subpentaedrus* (Jiang). The specimens of *O. subpentaedrus* obtained from the Zhongyicun Member of the Shangsuan Phosphorus Mine section in Jinning, Yunnan are abundant and are preserved relatively intact. More research is necessary to understand the classification of these groups.

*Meishucuchiton* Yu, 1987 was established with *M. vulgarus* Yu (1987b, plate 15 figures 4–10: Figure 9E–I) as the type species. Its generic diagnosis is as follows: “Shell very small, elongate, possibly belong to verminoid polyplacophorans. Intermediate valves heart-shaped, slightly wider than long. Anterior margin narrowly rounded. Latero-posterior corner obtusely rounded; posterior margin with a median sinus. Tegmentum weakly divided into central and lateral areas; central area widely convex, occupying most part of the dorsum, with a slightly raised apex; lateral areas small, subtriangular. Margin of valve with a narrow marginal edge. Head and tail valves unknown.” (Yu 1987b: 110–111). This genus somewhat resembles *Loechiton* Smith (1964) from the Lower Ordovician of southern Oklahoma. It is easily distinguished from the latter by the heart-shaped intermediate valves and smaller lateral areas.

At a glance, *Meishucuchiton vulgarus* Yu (Figure 9E–I) appears similar to *Eohalobia diandongensis* Jiang (Jiang in Luo et al., 1982, plate 21, figures 5–6; Yu, 1987b, plate 66, figures 1–11; Figure 9J–K) in dorsal view, but the differences are: (1) In *Meishucuchiton vulgarus*, the intermediate valve is nearly heart-shaped in dorsal view, while in *Eohalobia diandongensis*, it is elongately round or subovate. (2) In *Meishucuchiton vulgarus*, the dorsal side is divided into central and lateral areas, while *Eohalobia diandongensis* it is undifferentiated. (3) In *Meishucuchiton vulgarus*, the apex is slightly protruding, while in *Eohalobia diandongensis*, it is bluntly rounded. Here the intermediate valve, with its dorsal side divisible into different areas as observed in *Meishucuchiton vulgarus*, indicates an essential characteristic of the Polyplacophora.

It must be pointed out that the writer (Yu, 1987b) established *Meishucuchiton vulgarus* Yu, but it is misspelt as "Meishucunicus" vulgarus Yu, in Qian and Bengtson's monograph (1989: 108). *Meishucunicus* was established by Jiang (1980) with *Meishucunicus campyluran* Jiang as the type species. It represents another group entirely different from *Meishucuchiton*, and therefore they should not be lumped together.

**Jinkenites – A WONDERFUL FOSSIL**

Yu (1988, plates 1–2; Figure 10A–D) described the well-preserved earliest Cambrian fossil *Jinkenites zhaoi*. However, in Qian and Bengtson’s monograph, *Jinkenites zhaoi* Yu is also attributed to the genus *Canopoconus* Jiang, 1982 (Jiang in Luo et al., 1982: 193; Qian and Bengtson, 1989: 89; Bengtson, 1992a: 403). In fact, *Jinkenites* represents a fossil animal with several anterior marginal spines and peculiar spines on the dorsal side and is entirely different from the genus *Canopoconus* Jiang.

Noting that Bengtson (1992a: 403–404) reconsidered *Canopoconus* Jiang 1982 as a junior
Figure 11  *Paracarinichites sinensis* Qian and Jiang. The collection number of Sample A, x 27 (NIGP 106878) and B, x 30 (NIGP 106882) are 159a. They are collected from Section I (after Qian and Bengtson, 1989, p. 8). The collection number of sample C, x 40 (NIGP 89505) and sample D, x 20 (NIGP 89575) are YXX-4. They are collected from Section II (after Qian, 1989, p. 11).

synonym of *Maikhana zhegallo* (Zhegallo in Veronin et al., 1982), then a further likely synonym of *Maikhana calvata* (Jiang) (Jiang in Luo et al., 1982: 193, plate 21, figure 1; Qian and Bengtson, 1989: 91, figure 57) is "Purella" *squamulosa* Qian and Bengtson (1989, figure 61; Bengtson, 1992a: 410; Figure 10E-H). Judging from the smooth, rounded apical region and the scaly-surface pattern, there is no great difference between "Purella" *squamulosa* and *Maikhana calvata* (Jiang). A great number of specimens indicate that they belong to the same genus and possible species, and are different from *Purella*. The latter was established by Missarzhevsky (1974: 184), with *Purella cristata* Missarzhevsky as the type species. The Chinese species *Purella tianzhushanensis* Yu (1979: 253, plate 3, figures 18–19; 1987a, plate 3, figures 14–15; 1987b: 189, plate 37, figures 6–9, Text-figure 56; Figure 101–K) is closely related to *P. cristata* Missarzhevsky (1974, plate 23, figures 3–5) from the Lower Cambrian Tommotian Stage of Siberian Platform, but differs from the latter in the more bluntly rounded dorsal ridge, in the steeper subapical surface and in having spiral lines. However, in the undeveloped dorsal ridge, smooth and rounded apex and the imbricating scale-like protrusions, "Purella" *squamulosa* is quite different from *Purella cristata* and *P. tianzhushanensis*, but closely resembles these features of the genus *Maikhana*.

**SOME COMMENTS ABOUT THE FOSSIL LOCALITIES AND HORIZONS IN QIAN AND BENGSTON'S 1989 MONOGRAPH**

All the fossils described in Qian and Bengtson’s monograph were provided by Qian alone. The fossils were collected from the Meishucun section of Jinning and Baizai section and Xianfeng section of Xundian by Yu, Qian and others in 1980. However, in the collection, those fossils from the Meishucun section are labelled from beds 3–13, while all of the specimens from bed 10 of the Xianfeng section bear only one collection number 159a in their monograph. Among the 57 species under their description, 36 species were collected from the Meishucun section, while the remaining 21 species are from only the Xianfeng section. The 36 species from Meishucun section include 9 species, such as *Archiasterella cf. pentactina* Sdzuy, *Allonia? tetralathlis* (Jiang), *A. erroneousa* Jiang, *A.? simplex* Jiang, *Halkieria stenobasis* (Jiang), *Sinosachites flabeliformis* He, *Lapworthella rete* Yue,
Earliest Cambrian Polyplacophorans

Tannouolina zhaoxvngtangi Qian and Bengtson and Coleoloides typicus (Walco) which have also been found in the Yu’anshan Member of the Chiangchussu Formation. The remaining 27 species separately yielded from the Zhongyicun, Dahai and Badaowan Members of the Tongying Formation. The 21 species from Xianfeng section bearing the collection number 159a are all collected from the Zhongyicun Member of the Xianfeng section (Figure 11, section I). The present writer has some doubts about the locality and horizon of the collection number 159a specimens.

The Xianfeng section, one of the important sections in eastern Yunnan, is near the Damaidi village, about 23 km west of Xundian County. There the writer and Qian together systematically collected the samples (Coll. No. XD 1-4; X = Xianfeng section (Figure 11, section 1). The present writer has some doubts about the locality and horizon of the collection number 159a specimens.

The Xianfeng section, one of the important sections in eastern Yunnan, is near the Damaidi village, about 23 km west of Xundian County. There the writer and Qian together systematically collected the samples (Coll. No. XD 1-4; X = Xianfeng section, D = Damaidi village), based on the study of previous authors, without personally measuring the section. The section has been measured by many people, who collected much material, using glacial acetic acid treatment on the matrix. Some fossils have been extracted from the ore, but only a few are well preserved. This is because the massive phosphorites in the Zhongyicun Member are medium-bedded, compact and solid. However, fine fossils from number 159a are shown in Qian and Bengtson’s monograph.

The Baizai section is located about 1 km west of Baizai village which is about 10 km north of Xundian county. This section is a test pit numbered TC 101, where the slopes on both sides are covered with dense vegetation, and the outcrops are very well preserved. This is because the massive phosphorites in the Zhongyicun Member are medium-bedded, compact and solid. However, fine fossils from number 159a are shown in Qian and Bengtson’s monograph.

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The writer also wishes to thank the people, who collected much material, using glacial acetic acid treatment on the matrix. Some fossils have been extracted from the ore, but only a few are well preserved. This is because the massive phosphorites in the Zhongyicun Member are medium-bedded, compact and solid. However, fine fossils from number 159a are shown in Qian and Bengtson’s monograph.

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REFERENCES


Earliest Cambrian Polyplacophorans


Acanthodian microremains from the Frasnian Gneudna Formation, Western Australia

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Abstract - The scale variation seen in articulated acanthodian specimens (Diplacanthus horridus and Rhadinacanthus longispinus) from the Natural History Museum, London is illustrated to determine whether particular body regions on acanthodians display distinctive scale morphologies. This study has shown that, in the specimens observed, the head, shoulder girdle, lateral line, anterior flank, posterior flank, tail and fin spine insertion points are all characterized by different scale types. Isolated acanthodian scales found in residues from the Gneudna Formation, Western Australia, are assigned to different body regions. Scales determined as coming from the same body region were compared, and from these comparisons two species, Acanthodidae gen. et sp. indet. and Cheiracanthus sp., have been recognized.

The ratio of acanthodian scales to thelodont scales in different stratigraphic levels in the type section was compared to determine if these ratios are a reliable guide to the depositional environment. A traditional environmental interpretation of the microvertebrate ratios is not supported by lithological evidence or conodont abundance. It is concluded that the differences in this ratio do not add significant information for the interpretation on the depositional environment of the Gneudna Formation.

INTRODUCTION
The Acanthodii is a major group of Palaeozoic fishes that occurs on all continents. They occur in rocks ranging from Lower Silurian to Permian age (Denison, 1979). Often acanthodians are known only from disarticulated material, with their scales and fin spines commonly represented in microvertebrate assemblages (for comprehensive reviews see Denison, 1979; Turner, 1991). Due to the rarity of complete specimens, the overall morphology of acanthodians is poorly known. The majority of Devonian articulated material in the United Kingdom comes from the Welsh Borderland, the Caithness region, and Midland Valley of Scotland. Sites include: Turin Hill (Angus, Scotland), Achanarras County (Scotland) and Wayne Herbert Quarry (south-west Herefordshire, England) (Watson, 1937; Miles, 1973). In Canada articulated material has been obtained from the Delorme Formation, Northwest Territories (Russel, 1951; Bernacek and Dineley, 1977), and the Escuminac Formation (Gagnier, 1996; Gagnier and Wilson, 1996). In disarticulated material intra-specific scale variation is harder to determine. Gross (1973) considered isolated scales Wells (1944) had attributed to four species, to represent the scale variation of one species, which he synonymized as Cheiracanthoides comptus. Gross (1973) stated that it was possible that different regions of the body could bear special forms of scales. He synonymized two scale types, that Wells (1944) had described as two Acanthoides spp., as Acanthoides ? dublinensis (Gross, 1973).
Acanthodians are only represented by disarticulated scales in the type section of the Gneudna Formation (Figure 1) in the Carnarvon Basin, Western Australia (Figure 2). This makes identification of the material difficult, especially to the species level. However, by comparing the morphology of isolated scales from the Gneudna Formation with scales from different body regions in described articulated acanthodians, the identification and taxonomic study of isolated scales is shown to be possible.
MATERIALS AND METHODS

To determine variation in scale morphology of different body regions in acanthodians, fully and partially articulated specimens at the Natural History Museum, London were examined. Four acanthodian taxa were studied. The difference in scale morphology of two acanthodians, *Diplacanthus horridus* and *Rhadinocanthus longispinus*, are described. In addition, published descriptions of acanthodian scale variation were used for comparison.

The study is based on isolated scales from the Gneudna Formation, Williambury Station, Western Australia. Scales described in this paper come from the residues of limestone samples digested in 10% acetic acid. The scanning electron micrographs were made on a Philips 505 at the Centre for Microscopy and Microanalysis, The University of Western Australia.
Australia. Sections of scales were ground by hand and examined under confocal and light microscopes. Specimens from the Gneudna Formation have been deposited in the collections of the Western Australian Museum (WAM).

Comparative Material
P61716 *Rhadinacanthus longispinus* Agassiz, 1844 complete articulated specimen.
P6188 *Rhadinacanthus longispinus* Agassiz, 1844 complete articulated specimen.
P6757 *Diplacanthus horridus* Woodward, 1892 complete articulated specimen.
P61859 a, b *Cheiracanthus murchisoni* Agassiz, 1835 incomplete articulated specimen missing the head. In part and counterpart.

**DESCRIPTION OF SCALE VARIATION IN ACANTHODIANS**

Various trends in scale variation have been reported in acanthodians (Miles, 1973; Young, 1995; Gagnier, 1996). With the exception of Watson (1937) who noted considerable variation of the scale size over the body of acanthodians and Gagnier and Wilson (1996), who noted that scale size decreased posteriorly in fin web scales, most studies (e.g. Miles, 1973; Valiukevicius, 1992) have concentrated in determining scale variation within species. Here, four articulated specimens from three different genera were examined to determine if some variation is consistent at a higher taxonomic level. The scale variation present in two of the species examined, *R. longispinus* and *C. murchisoni*, was illustrated in Young (1995, figures 6, 9) and the variation in the squamation of *P. menieri* was described by Valiukevicius (1992). The scale variation present in *D. horridus* and additional variation noted in *R. longispinus* is described below. By comparing the variation in the squamation of these four genera, morphological scale features that characterise different parts of the fish body have been established. Therefore, description of the unchanging scale features gives an indication of the body position from which an individual scale originated. By comparing scales from the same body region, an indication of the variation within a species, and of the variation between species, can be determined. As a result, more reliable estimates of the numbers of acanthodian species present in microvertebrate assemblages can be realized.

Scale Variation in *Diplacanthus horridus*

Seven distinct scale morphologies are identified from different body regions of *D. horridus*, Upper Devonian, Scameneec Bay, Canada. In addition there are large dermal tesserae on the cranial roof and part of the narrow ring around the orbit. The size of the flank scales is, on the whole very similar, but they do decrease in size a little towards the dorsal and ventral surfaces and toward the tail. The scales on the fin webs are extremely small, and become smaller as they are traced down toward the margin of the fin. The scales bordering the lateral line are enlarged but have the same shape as those above and below them. The scales located below the lateral line and anterior to the pectoral fin spine (pfs) are high with a tumid base and well-defined neck (Figure 3). The crown is rounded anteriorly and overhangs the base posteriorly. There is an ornament of posteriorly converging ridges on the crown surface. Scales above the lateral line and in front of the anterior dorsal fin (dfa) have an identical crown shape and surface ornament; the base, however is not as high as in scales below the lateral line (Figure 3A). Mid-flank scales at the level of the anterior dorsal fin have a tumid base with a well-defined neck, and the crown overhangs the base posteriorly. The ridges on the crown surface, however, extend only to the middle of the scale (Figure 3B). Scales anterior to the pelvic fin spine (pls) are very high with the crown separated from the base by a well defined, constricted neck. At the junction of the base with the neck, the base flares laterally, extending beyond the width of the crown (Figure 3C). Scales anterior and posterior to the posterior dorsal fin spine (dfp) are also high with a well defined, constricted neck and lateral flaring at the neck-base junction (Figure 3D-E). These scales however, are not as high and the lateral basal flaring is not as extensive as in scales anterior to the pelvic fin spine. Ventral scales from around the anal fin spine (af) (Figure 3E) are higher than dorsal scales from around the dorsal fin spine (Figure 3D). In contrast to anterior body scales the caudal body scales are relatively flat with a poorly defined neck. They are rounded anteriorly and posteriorly and the crown does not overhang the base. The regional variation present on the caudal fin can be compared to that of *Acanthodes*, in which four zones have been described (Miles 1973).

Scale Variation in *Rhadinacanthus longispinus*

The scale morphologies evident in *D. horridus* are also present in *R. longispinus* (Middle Devonian, Old Red Sandstone, Cruaday, Orkney). However, the head is covered by irregular scales and there is a transitional area between the head and body, which is covered by large, irregularly arranged scales. The scales on the flank of the fish are similar in size. There is a reduction in the scale size towards the dorsal and ventral surfaces and toward the tail. The fin web is covered with a mosaic of very small rhombic scales. The lateral line is bordered by enlarged scales similar in shape to the scales above and below them. The scales located below the lateral line and anterior to the pectoral fin spine (pfs) are high with a
Acanthodian microremains from Frasnian Gneudna Formation

Tumid base and well-defined neck. The crown is rounded anteriorly and overhangs the base posteriorly. There is an ornament of posteriorly diverging ridges on the crown surface. There is a small button on the centre of the scale base. Scales above the lateral line and in front of the anterior dorsal fin (dfa) have an identical crown shape and surface ornament; but the base is not as high as in scales below the lateral line, and the button is absent. Mid-flank scales at the level of the anterior dorsal fin have a tumid base with a well-defined neck, and the crown overhangs the base posteriorly. Scales anterior to the pelvic fin spine (pls) are very high with the crown separated from the base by a well defined, constricted neck. At the junction of the base with the neck, the base flares laterally, extending beyond the width of the crown. Scales anterior and posterior to the posterior dorsal fin spine (dfp) are also high with a well defined, constricted neck and lateral flaring at the neck-base junction. These scales however, are not as high and the lateral basal flaring is not as extensive as in scales anterior to the pelvic fin spine. Ventral scales from around the fin spine are higher than dorsal scales from around the fin spine. In contrast to anterior body scales the caudal body scales are relatively flat with a poorly defined neck. They are rounded anteriorly and posteriorly and the crown does not overhang the base.

Discussion

Several morphological body scale features were found to remain constant between these genera, and these allow the allocation of individual scales to a particular body region. The scale morphology changes gradually from the anterior region to the caudal region in acanthodians, and from the lateral line to the dorsal and ventral margins. Because the morphological changes are gradual, several trends common to different genera of acanthodians, have been identified. The anterior flank scales of acanthodians have a high profile, and are rhombic in shape. The shape of the scales progressively changes from rhombic to elongate along the flank, but they continue to have a high profile. Towards the caudal region the scales revert to being short and rhombic again, though they differ from scales from the anterior region in having a very low profile. In addition to the change in scale shape, there is a corresponding reduction in the crown ornament (when present) from the anterior region to the caudal region (e.g. Diplacanthus striatus Agassiz, 1844; Cheiracanthus
latus Egerton, 1861; Euthacanthus macnicoli, Powrie, 1864; Parexus falcatus, Powrie, 1870; R. longispinus; and D. horridus). Acanthodians also have a number of specialised scales, particularly around the lateral line (Watson, 1937), the shoulder girdle (Miles, 1973) and the tail (Miles, 1970). In addition there are specialised scales around the bases of the fin spines, but these scales vary between genera. In Diplacanthus, Rhadinacanthus and Ptomacanthus these scales have a very high profile in comparison to other body region scales. The scales from around the bases of the dorsal fin spines have a higher profile than scales from around the base of the ventral fin spines. The crown ornament on the scales from around the bases of the dorsal fin spines does not differ from the flank scales around them but; these scales have anteriorly flared bases with well constricted necks (R. longispinus and D. horridus, Figure 3). In Culmacanthus and Mesacanthus the base of the fin spine is surrounded by enlarged, flat scales (Watson, 1937; Long, 1983).

SYSTEMATICS OF THE GNEUDNA ACANTHODIAN SCALES

Order Acanthodida Berg, 1940
Acanthodida gen. et sp. indet.

Material Examined
WAM 98.4.1; WAM 98.4.2 and 500 other complete scales (WAM 99.8.69-74)

Horizons
KT Beds 4, 12, 20, 21A, 22, OFB (Figure 1)

Description of Morphotype 1 (Figure 4A-C)
This scale is pale orange in colour with a thin translucent crown. The outline of the scale is rhombic. The anterior edge does not overhang the base (Figure 4A-B), but the posterior edge overhangs the base slightly. The tumid and relatively high base is separated from the crown by a well defined neck. There are concentric growth rings visible on the base.

Description of Morphotype 2 (Figure 4D-E)
The outline of the scale is rhombic (Figure 4D). It is longer than scales of morphotype 1 (Figure 4A-B). The posterior edge of the unornamented crown overhangs the base. The constricted neck is well defined. Sharpey's fibre bundles are visible on the moderately high tumid base (Figure 4E).

Description of Morphotype 3 (Figure 4F-G)
The scale shape is rhomboid; the crown is thin and flat; the anterior edge is rounded and does not overhang the base (Figure 4F). There is no ornament on the crown surface. The neck is well defined and separates the crown from a low base. The base is shaped like a cross and there are visible Sharpey's fibre bundles (Figure 4G).

Description of Morphotype 4 (Figure 4H-J)
These scales are typically elongated in shape, the crowns being longer than wide (Figure 4I). The crown is thin with a shallow, mid scale depression. There are numerous pores opening onto the crown surface. Anteriorly, the crown is rounded and level with the base (Figure 4H). The posterior edge of the crown forms an acute angle and overhangs the base (Figure 4I). There is a narrow, well-formed neck separating the crown from the convex base (Figure 4H-J). The neck is deeper posteriorly than anteriorly, and there is no ornamentation visible. At the contact between the base and neck, the base flares to form a narrow ridge (Figure 4H-I). The base is higher than wide with clear Sharpey's fibre bundles visible (Figure 4H).

Histology
There appear to be microscopic dentine tubercles on the crown surface, similar to those described by Derycke and Chancogne-Weber (1995) (Figure 4C). There is a thick dentine layer on the crown (Figure 4K) with straight dentine tubules directed centripetally on the crown growth zones (Figure 4L). In longitudinal section, long tubules of dentine can be seen extending up the neck towards the centre of each growth zone (Figure 4K). The ascending canals are narrow, not much wider than the dentine tubules. The base is of acellular bone penetrated by numerous fine canals. Sharpey's Fibres are arranged in pyramidal layers in the base.

Allocation of Scales to Body Region
Although some acanthodians have scales with no crown ornament, considerable variation in scale morphology from different body regions is still apparent. The shapes of scales from Ischnacanthus gracilis Egerton, 1861 were described by Young (1995) as rhombic, sub-rhombic or polygonal, being relatively flat to gently convex and smooth. This same variation in shape and height is seen in the scales referred here to Acanthodidae gen. et sp. indet. above. Comparisons with articulated acanthodians (Young, 1995) suggest that the short, deep scales (morphotype 1) collected from the Gneudna Formation are from the anterior regions of the fish; the elongated, deep scales are from the flank regions (morphotype 2); the rhombic low scales with the cross-shaped base are from caudal regions (morphotype 3); and the scales with the lateral extensions to the base are from around the insertion points of fin spines (morphotype 4). As
Acanthodian microremains from Frasnian Gneudna Formation

Figure 4  Scales identified as Acanthodidae gen. et sp. indet. A-B, morphotype 1 – anterior body scales; C, microomament on crown surface; D-E, morphotype 2 – flank scales; F-G, morphotype 3 – caudal scales; H-J, morphotype 4 scales from around the base of the fin spine insertion points; K, sagittal section of a morphotype 1 scale; L crown section of a morphotype 1 scale. Scale bars = 1.0 mm.

the different smooth-crowned morphotypes in the Gneudna Formation samples correspond to variants found on an individual fish, they are assigned here to a single species. However, this will remain conjecture until a complete articulated specimen is found.

Taxonomic Assignment

The scales are referred to the Family Acanthodidae but are not assigned to any known genus or species. The assignment of isolated unornamented scales to a genus or species is difficult, due to a lack of diagnostic features. The Acanthodidae gen. et sp. indet. scales described here, evoke the description of Acanthodes guizhouensis Wang and Turner, 1985, in having an elongated posterior crown ending in an acute point, a slightly curved anterior margin and a depression near the centre of the crown. This species is recorded from the upper Famennian of Morocco (Derycke-Khatir, 1994) and China (C. Derycke personal communication 1998) and the Lower Carboniferous of China (Wang and Turner, 1985).

There are several other genera erected for articulated fish within the family Acanthodidae, including Mesacanthus Traquair, 1888, Protonaconthius Miles, 1966 and Traquairichthys Whitley, 1933, which have unornamented scales and cannot be distinguished from each other, based on only scale morphology. In addition to these is the genus
Acanthodes Agassiz, 1833 to which many isolated unornamented scales have been referred in the past. Zidek (1976) considered Acanthodes as a *nomen dubium* and Denison (1979) considered that many Devonian scales attributed to Acanthodes are not from that genus. Gross (1973) stated that scales characterized by unornamented crowns are found repeatedly among members of the acanthodian radiation. Wang (1984) also considered that true Acanthodes only occur in lower Carboniferous - Permian strata.

To date, the only articulated acanthodian known from the Lower Frasnian of Australia is Howittacanthus kentoni Long, 1986, recently placed in its own family Howittacanthidae by Zajic (1995). This family is considered to be closely related to the Acanthodidae because of comparable features in the jaw (Zajic, 1995). Like members of the Family Acanthodidae the Howittacanthidae and Mesacanthidae possess unornamented scales. This Howittacanthidae is represented by a single species, *H. kentoni*, and is only recorded from eastern Australia.

Family Cheiracanthidae Berg, 1940
Genus Cheiracanthus Agassiz, 1835
*Cheiracanthus* sp. indet.

Material Examined
46 complete scales (WAM 99.8.75-80)

Horizons
KT Beds 4, 9, 14, 21, 22 and OFB (Figure 1)

Description of Morphotype 5 (Figure 5A–B)
The crown is elongate, being longer than wide. An ornament of between 10–12 raised parallel ribs extends from the anterior edge to the posterior third of the scale (Figure 5A–B). There is a narrow unornamented rim around the margin of the scale (Figure 5A). The anterior edge of each rib bifurcates (Figure 5A). The anterior edge of the scale is rounded and slightly overhangs the base. There is a shallow mid-scale depression which is characteristic for *Cheiracanthus*. The posterior edge of the crown is pointed and overhangs the base. A well defined neck separates the crown and deep tumid base. The base is acellular.

Description of Morphotype 6 (Figure 5C–D)
This scale type is rhomboid. The anterior margin is rounded and the posterior margin is broken (Figure 5D). The anterior and posterior edges of the crown overhang the base. The crown surface ornament consists of 6–8 parallel ribs, which bifurcate anteriorly (Figure 5C–D). The ribs extend to the middle of the scale, disappearing towards the back. There is a constricted neck and a deep tumid base.

Description of Morphotype 7 (Figure 5E–F)
Morphotype 7 (Figure 5E–F) is very similar to morphotype 6. The anterior and posterior crown margins overhang the base (Figure 5H). The crown ornament consists of eight parallel ribs, which bifurcate anteriorly (Figures 5F–G). The ribs extend to the middle of the scale. The posterior margin of the scale is scalloped. There is a constricted neck and a deep tumid base.

Description of Morphotype 8 (Figure 5I–J)
The scale type is rhomboid in shape with a low profile (Figure 5I–J). The crown surface is very abraded with only traces of the ribbed ornament remaining (Figure 5I). As with the other scales described, there is an unornamented rim around the anterior edge of the scale. The crown does not overhang the base. There are four canals in the neck, which separates the crown from the flattened base. The base is shaped like a cross.

Description of Morphotype 9 (Figure 5G–H)
The specimens representing this scale type are abraded. They have a rhombic to elongate shape (Figure 5G–H). The posterior edge of the crown is scalloped and overhangs the base (Figure 5G). The ornament consists of 4–8 parallel ribs that bifurcate anteriorly. There is an unornamented rim around the margin of the scale. A well defined and constricted neck separates the crown and deep tumid base. The neck contains four canals. At the junction of the base and neck, the base flares laterally, approaching the width of the crown (Figure 5H).

Histology
The crown is composed of orthodentine. In sagittal section it can be seen that the main dentine tubules do not possess many side branches (Figure 5K). This is characteristic of *Cheiracanthus*. A series of growth zones can be seen along the anterior edge in sagittal section and along the dorsal and lateral edges in sagittal section. In the centre of the neck three ascending canals are present. One of these extends to the crown; the other two extend to the neck. The base is acellular.

Allocation of scales to body region
A greater degree of variation is present in acanthodian scales with crown surface ornament than in acanthodian scales that are unornamented. This is because the type of crown ornament may vary in addition to the shape of scales, depending
on the region of the body that the scales are located. The crown ornament in *Euthacanthus macnicoli* shows considerable variation in the number of ridges and the distance each ridge extends posteriorly along the crown surface (Young, 1995). A reduction in the length of the ridges on the crown surface from the anterior region to the caudal region of the fish is also observed in *Diplacanthus horridus* (Figure 3). There is also variation in the base of ornamented acanthodian scales. Gross (1973) observed that the height of the base increases towards the anterior of the fish in *Machaeracanthus bohemicus*. Relatively high scales with tumid bases occur in the anterior region of the fish, and scales with low bases occur in the caudal region of the fish (pers. observation). A greater variation in the shape and height of scale bases is apparent in *D. horridus* (Figure 3).

In *Cheiracanthus* sp., variation in the crown surface ornament and in the height and shape of the base can also be observed. Scales with a high profile and deep tumid base also have the most
numerous and longest ridges on the crown surface, suggesting that these scales came from the anterior region of the fish's body (morphotype 5). Scales in which the ridge number and length are less, but which still retain a high profile and tumid base (morphotypes 6 and 7), are considered to have come from the flank region of the fish. Scales that are relatively flat and have ridges only in the anterior third of the scale (morphotype 8), are interpreted as having come from the caudal region of the fish. Scales with a lateral extension above the tumid base (morphotype 9) are considered to have come from around the fin spine insertion points. These scales have correspondingly shorter and fewer ridges on the crown surface.

There are two characters that remain consistent in the crown surface ornament of Cheiracanthus sp. that suggest that all scales are from the same species. These characters are: the bifurcation at the anterior end of each ridge and the presence of a narrow, raised lip around the anterior edge of each scale. As with the Acanthodidae gen. et sp. indet. scales described above, all scale types from the different body regions present on acanthodians are represented in the samples from the Gneudna Formation. Accordingly, it is concluded that all Cheiracanthus sp. scales are from a single species.

**STRATIGRAPHIC DISTRIBUTION AND DEPOSITIONAL ENVIRONMENTS**

Thelodont scales have been used to indicate bathymetry in Early Devonian sediments. A higher proportion of thelodont scales compared to acanthodian scales is considered to represent nearshore, or shallow water conditions (Märrz and Einasto, 1978; Turner, 1984, 1999; Burrow, 1997). The microvertebrate assemblages from the type section of the Gneudna Formation do not support these findings.

Thelodont scales are proportionally most abundant in the beds KT1-5, KT6-9 and KT10-18 (Figure 1). These beds, which consist of crinoidal/brachiopod packstone, have been interpreted as representing a shallow nearshore environment. In the beds KT6-9 ptyctodont remains (Long and Trinajstic in press) are well preserved and in some cases partially articulated, indicating lower energy, offshore depositional conditions. Here thelodont scales are more abundant than acanthodian scales. In the upper part of the type section, from KT19 to 22 and OFB, thelodont scales are rare and acanthodian scales are most abundant (Figure 1). According to Märrz and Einasto (1978) these proportions should indicate an offshore environment. However, these beds are interpreted as having been laid down in extremely shallow water, with sediments mainly consisting of a well-sorted shell hash having a high quartz content.

There are three possible reasons why thelodonts/acanthodian scale number ratios do not provide here a reliable environmental indicator in the Gneudna Formation. During the Givetian and Frasnian, the thelodonts declined in number and diversity, with no thelodonts known after the Frasnian. Thus the ratios of acanthodian to thelodont remains may only be an effective environmental indicator for the Early and Middle Devonian, when thelodonts were diverse and abundant, and not hold for the Frasnian. Evidence to support this comes from the study of conodont ratios, in particular the ratios of Icriodus to Polygnathus, in the section. Like thelodonts, the ratios of certain conodonts have been successfully used as environmental indicators. In the Gneudna Formation the conodont ratios (R. Nicholl personal communication 1997) are consistent with the lithological interpretations of the depositional environments for each interval.

Secondly, many beds within the Gneudna Formation have been extensively affected by post-depositional dolomitization. Thin sections of these beds show many fossil ghosts and the micro-remains recovered from residue are poorly preserved. The actual fossil ratios of the dolomitized beds may be skewed due to preservation bias as a result of diagenic changes.

Thirdly, it is considered that the microvertebrate remains in the area where the type section of the Gneudna Formation was deposited, with the exception of those in bed KT7, have been transported before deposition. Microvertebrate remains are disarticulated and predominantly occur in packstone, due to post-depositional concentration. The Gneudna Formation is also unusual in that there is a complete absence of acanthodian fin spines in the section. The fish-bearing units in the Gneudna Formation are generally well sorted and the absence of acanthodian fin spines could be explained through winnowing.

The difference in the proportion of acanthodian scales to thelodont scales does not provide any bathymetric information that would indicate the depositional environment of the Gneudna Formation.

**ACKNOWLEDGEMENTS**

My thanks to Dr Per Ahlberg, for allowing me to work on the collections of the Natural History Museum. To Dr Kim Dennis-Bryan for her hospitality while in Britain and help in finding my way through the collections of the Natural History Museum. To Carole Burrow for her valiant attempts...
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The Cenozoic Brachiopoda of the Bremer and Eucla Basins, southwest Western Australia

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Abstract - The brachiopod fauna from the Late Eocene Bremer Basin and Middle Eocene to Pliocene Eucla Basin are described. Nineteen species have been recorded from the six major deposits in the two basins. Two new species, Terebratulina christopheri and Liothyrella labiata, are described. Two described species are reassigned from Terebratula to Liothyrella: T. bulbosa (Tate, 1880) and T. subcarnea (Tate, 1880). The close relationship between the species found in the basins and those found in Late Eocene to Miocene deposits in southeastern Australia is examined. The later appearance of species in eastern South Australia, Victoria and Tasmania may well accord with the separation of Australia from Antarctica. The relationship between genera in Australia, New Zealand and Antarctica is also examined with implications for the evolution of Southern Hemisphere Brachiopoda.

INTRODUCTION

The brachiopods described herein from the Bremer Basin and Eucla Basins in the southern margins of Western Australia.

Stratigraphy of Bremer Basin (Figure 1)

The Plantagenet Group of the Bremer Basin in the south-west of Western Australia extends from North Walpole to east of Esperance. Cockbain (1968c) formalised the Group as consisting of the Pallinup Siltstone and the Werillup Formation (Figure 1). Chapman and Crespin (1934) very briefly described four brachiopod species from the Plantagenet Beds, Western Australia.

The Plantagenet Beds are described by Clarke and Phillips (1955) as “a horizontal series of conglomerates, sandstones, and clays overlain by the very characteristic and widely distributed “spongolite” (a sandy or silty rock containing abundant sponge spicules, and occasional entire sponges) in which, here and there, are lenses of limestone.”

Cockbain (1968c) described the Werillup Formation as consisting of ‘grey and black clay, siltstone, sandstone, lignite and carbonaceous siltstone.’ The Werillup Formation contains both marine and non-marine strata overlaying a Precambrian surface of sands and granite. The non-marine material was most likely produced in peat swamps formed in hollows that became land locked after “an initial marine phase”. A further shallow marine transgression resulted in deposits of silt, sand, clay and limestone. The Nanarup Limestone, probably due to this latter transgression, is described as a Member of the Werillup Formation and is a yellow-white friable bryozoan limestone. It is best exposed at the Nanarup Lime Quarry. Quilty (1981) suggested that, due to the lack of sorting and presence of complete echinoids and articulated brachiopods, current activity was negligible at the time of deposition. He further suggested that from the spatial distribution of the limestone immediately ‘east of present-day granite hills’ that it “accumulated in the lee of islands, protected from the easterly-moving currents” and detritus. He proposed a maximum depth of deposition of 35 m.

The Pallinup Siltstone overlies the Werillup Formation. It extends to the Precambrian basement in areas either not covered in the transgression previously mentioned or exposed by erosional effects. Cockbain (1968c) described the Pallinup Siltstone as typically ‘white, brown or red siltstone and spongolite.’ He concluded that this was laid down in a shallow transgressive sea with negligible input of terrigenous material, allowing sponges to thrive. The actual thickness of the Pallinup Siltstone varies and in the Norseman area there is some dispute over the correlation (Cockbain, 1968a; Backhouse, 1969). Darragh and Kendrick (1980) described the Pallinup Siltstone as resulting from “deposition... accompanied downwarping and transgression along the newly formed continental margin in the aftermath of the geological separation of Australia and Antarctica ... The Pallinup Siltstone formed in a shallow shelf environment with well-circulated water of normal marine salinity”. They inferred a depth of deposition of 76 m but Fickett (1982) suggested this estimate might be too great.
Churchill (1973) and Clarke (1994) inferred a depth of deposition of approximately 150 m. The estimates of depth of deposition by Darragh and Kendrick (1980) are therefore possibly conservative.

**Age**

The Werillup Formation is regarded as late Middle Eocene. This is supported by the presence of the Dasycladacean algae, *Larvaria* and *Neomeris* (Cockbain 1969) and the foraminifer *Asterocylinia* (Cockbain 1967). The Nanarup Limestone Member has also been determined as Late Eocene from the presence of the nautiloids *Aturia clarkei*, *Teichertia prora* and *Cimonia felix* (Cockbain 1968 b, c) as well as foraminifers reported by Quilty (1969). The Pallinup Siltstone is of similar age, again from the presence of the nautiloid *Aturia clarkei* and foraminifer reported by Backhouse (1969), Cockbain (1968a) and Quilty (1969). The foraminifers correspond with Ludbrook’s “Tortachilla microfauna” (Cockbain 1968c).

The two transgressions discussed above are the Tortachilla Transgression assigned an age of 41 Ma and the Aldinga Transgression that is estimated at 37 Ma (McGowran 1989).

**Palaeoclimate**

Due to the presence of about 95% dextrally coiled foraminifer Quilty (1969) suggested that these sediments were deposited in a warm environment. Temperatures in the Southern Ocean have been discussed by Kemp (1978) who showed that they were warmer than the present day, probably influenced by Indian Ocean and Proto-Leeuwin currents. The bivalves from the Pallinup Siltstone at Walpole suggest a temperate climate (Darragh and Kendrick, 1980). Recent work on the gastropods (G.W. Kendrick, personal communication) suggests that they are warm water species. These views are supported by the palynological studies of Hos (1975), the presence of the sponge *Vaceletia progenitor* (Pickett, 1982), the echinoid *Echinolampas* and the marsupiate echinoid, *Fossulaster* (McNamara, 1994) as well as the microflora described by Balme and Churchill (1959) and Cookson (1954). McNamara (1994) suggested the Pallinup Siltstone probably was deposited in a cooler sea than that of the first transgression (still warmer than present conditions).

Clarke (1994) and Churchill (1973) described flora, including mangroves from the hinterland of the Late Eocene as being semi-tropical to tropical. The climate of the area was therefore quite different to that found there today.

**Overview**

In summary, it appears, then, that there were two marine transgressions during the Late Eocene. The first (Tortachilla Transgression) producing swamps, depositing silts, clays and the Nanarup Limestone
Member, while the second (Aldinga Transgression) produced the spongeite and siltstone of the Pallinup Formation. These transgressions would have washed around the granite outcrops of the southwest such as Mt Frankland, Granite Peak (Darragh and Kendrick, 1980) and the Porongurup Range that would then have appeared as islands. The Aldinga Transgression would have reached the base of the Precambrian uplifted deposits of the now Stirling Range, possibly producing an island or headland.

Stratigraphy of the Eucla Basin formations (Figure 2)

The Wilson Bluff Limestone Formation consists of four main subsections. The lowest is a thick calcarenite made up of bryozoan fragments in a microcrystalline calcite matrix. Within this section are found echinoid tests, brachiopods, bivalves, sponges and foraminifers. The overlying subsection is a thin layer, similar to that described above, but containing oysters as well as the other fauna. Overlying this is another similar layer, without oysters and less fossiliferous. The top layer is a hard white limestone containing bryozoan fragments and abundant brachiopods (Lowry 1970).

The Wilson Bluff Limestone is believed to extend several metres below sea level. It is overlain disconformably by the Abrakurrie Limestone and overlies the Hampton Sandstone. The Wilson Bluff Limestone can be best described as a poorly sorted white, compact packestone with bryozoan fragments in lime mud. Chert nodules can be found in all but the lowest 12 m. Some compaction structures are present and current bedding is common. It is found throughout the Eucla Basin but is replaced by the Toolinna Limestone that it abuts in the south-west (Lowry, 1970).

Lowry (1970) suggested that it was deposited in a flooded old river valley system and formed a wide continental shelf of normal marine salinity. Foraminifer suggest the lower section was deposited in water greater than 76 m deep, whilst the upper section was originally shallower. The abundance of lime mud may have been due to baffles formed by sponges, non-calcareous alga or sea grasses.

An Eocene age was originally suggested for the formation. This has been confirmed by the discovery of the Late Eocene bivalve *Notostrea lubra*, and *Australanthus longianus*, an echinoid of the same age. Foraminiferal assemblages suggest that the uppermost part is Late Eocene and the base is Middle Eocene (Li et al., 1996).

Abrakurrie Limestone consists of two parts. These

![Figure 2](image-url)  
*Figure 2* Map of the Eucla Basin indicating the fossil sites in the various deposits. 1 = Murra-el-elevyn Cave, 2 = Tommy Graham Cave, 3 = Haig Cave, 4 = Firestick Cave, 5 = Mullahmullang Cave, 6 = Abrakurrie Cave, 7 = Weebubbie Cave (derived from Lowry, 1970).
are the lower friable bryozoan calcarenite and an upper indurate bryozoan calcarenite, both moderately well sorted. Echinoid tests, fragments and spines, brachiopods and bivalves are common throughout. The echinoids are most abundant at the top of the formation. Nodules of coralline algae are also present. The rock is generally coarse grained but ranges from granular to fine grained. Beds are mostly grainstones with some packstones. Large scale cross bedding is prominent (Lowry, 1970).

The Abrakurrie Limestone is developed in the central basin and is thickest at Madura where it is exposed in numerous caves. The thickest known exposure is in Mullamullang Cave where it extends from 17.5 m below the surface to 91 m. This formation lies disconformably on the Wilson Bluff Limestone and the Toolinna Limestone. It is overlain by the Nullarbor Limestone. The echinoid fauna is typical of the Janjukian-Longfordian (Middle Oligocene-Early Miocene) and the foraminifers are mostly long ranging benthic forms (Lowry 1970).

Lowry (1970) suggested that the Abrakurrie Limestone was deposited on a shallow open shelf of normal marine salinity. He suggested sea temperatures were probably warmer than at present. James and Bone (1992) interpreted the limestone as a cool-water deep shelf deposit that accumulated in water depths greater than 70 m on the inner part of the Eucla Platform. They suggested a model of deposition and cementation on a carbonate shelf swept by open ocean swells. Deposition occurred when sea level was high. Hardgrounds formed when sea levels dropped and erosion took place due to wave abrasion. The James and Bone (1991) model is based on modern swell dominated shelves. They suggested sea-level fluctuations were due to storms and periods of glacial activity. The lack of calcareous red alga brings them to the conclusion that the deposition was below the zone of active coralline growth. Li et al. (1996) concluded that the Abrakurrie Limestone is late Oligocene to earliest Miocene. It approximates to foraminiferal zones P22 to N4. They suggested that it was deposited during the second-order supercycle T1, which correlates broadly to the Janjukian Stage of southern Australia N4 (Li et al., 1996).

The Toolinna Limestone consists of "medium to very coarse grained well sorted current bedded, bryozoan calcarenite" (Playford et al., 1975). The type section is 55 m high and found on the cliffs at Toolinna Cove in the southwest corner of the Eucla Basin. The macrofauna is similar to that found in the Wilson Bluff Limestone and therefore the age is determined as Late Eocene (Playford et al., 1975). Li et al. (1996) suggested that it is Middle Eocene to Early Miocene and that it could belong to the Abrakurrie Limestone due to the benthic foraminiferal fauna that differs to the Wilson Bluff Limestone.

The Roe Calcarenite is a thin, sandy limestone of Pliocene age that forms the surface of the Roe Plains (Figure 3) in the southern Eucla Basin. Its stratigraphy and age correlation are fully outlined in Craig (1999). One species of brachiopod,

![Figure 3 Map of the Eucla Basin showing the Roe Plains and the Hampton Range Repeater Tower, the principle fossil site for the Roe Calcarenite.](image-url)
Cenozoic Brachiopoda of the Bremer and Eucla Basins

*Neothyris rylandae*, has been described from the deposit (Craig, 1999).

**MATERIAL AND METHODS**

The brachiopods examined are housed in the Museum of Western Australia (WAM), the Geological Survey of Western Australia (WAM numbers) and the University of Western Australia (UWA). Specimens from the Museum were principally collected by Dr T. Darragh, Mr G.W. Kendrick, Dr K.J. McNamara and family, Mr R.S. and Mrs Z.I.T. Craig and Mr I. Green.

The specimens were cleaned from the matrix using dental tools. Where possible, the interiors were also cleaned. Serial grinding was conducted on complete specimens using a large wheel grinder and sections were drawn using a camera lucida microscope.

Photographs were taken with a Nikon F 90 X camera with a macro lens and each specimen was prepared for photography with a coating of ammonium chloride.

**SYSTEMATIC PALAEONTOLOGY**

Phylum Brachiopoda Dumeril, 1806

Subphylum Craniiformea Popov, Bassett, Holmer & Laurie, 1993

Class Craniata Williams, Carlson, Brunton, Holmer & Popov 1996

Order Craniida Waagen, 1885

Superfamily Craniacea Menke, 1828

Family Craniidae Menke, 1828

Genus *Westralicrania* Cockbain, 1966

**Types Species**

*Westralicrania allani* Cockbain, 1966.

*Westralicrania zenobiae* Craig, 1997

Figure 8 A–G

*Westralicrania zenobiae* Craig, 1997: 311–315, Figures 1, 2, A–L.

**Material Examined**

*Holotype*

WAM 94.29, (ventral valve) Nanarup Lime Quarry, Nanarup Limestone, Werilup Formation, Bremer Basin.

*Paratypes*


**Other Material**


Eucla Basin: WAM 88.371, 373, 873, 94.28, Israelite Bay, Toolinna Limestone, Late Eocene.

Remarks

The original description by the author remains unchanged. This species was described from the Late Eocene, Nanarup Limestone, Bremer Basin, Western Australia (Craig 1997). The material listed above was used in the description of the species by Craig (1997).

Order Terebratulida Waagen 1883

Suborder Terebratulidina Waagen, 1883

Superfamily Terebratuloidea Gray, 1840

Family Terebratulidae Gray, 1840

Subfamily Terebratulinae Gray, 1840

Genus *Liothyrella* Thomson, 1916

**Type Species**

*Terebratula uva* Broderip, 1833.

*Liothyrella labiata* sp. nov.

Figures 4, 9 A–D

**Material Examined**

*Holotype*

WAM 94.61 Nanarup Lime Quarry, Nanarup Limestone, Werilup Formation, Bremer Basin.

*Paratypes*

WAM 94.62-64, Nanarup Lime Quarry, Nanarup Limestone, Werilup Formation, Bremer Basin.

**Other Material**

Bremer Basin: WAM 94.61-64, Nanarup Lime Quarry, Nanarup Limestone, Werilup Formation, Bremer Basin.

Eucla Basin: F6110/1, Madura south cave; F6111/3, F6111/4, Murra-el-elevyn Cave, Burnabbie, Wilson Bluff Limestone, Late Eocene.

**Diagnosis**

*Liothyrella* with sulciplicate anterior commissure; beak suberect, large lip (labiate), foramen large.
Description

*Exterior.* Shell ovate to subpentagonal, medium-sized, 9.7 to 35.5 mm long. Ventribiconvex, depth to 53% shell length. Widest anterior to mid-length, to 73% shell length. Shell smooth, finely and densely punctate, growth lines prominent anterior to mid-length. Folding on ventral valve incipient, double fold on dorsal valve in anterior third of shell to 60% shell width. Cardinal margin strongly curved; valves lateral edge gently rounded, lateral margin straight to incipiently sigmoidal; anterior commissure sulciplicate. Umbo truncated, beak suberect, labiate; beak ridges attrite. Foramen large, to 6.6% shell length, permesothyrid. Symphytium narrow, to 6.6% shell length, permesothyrid. Symphytium narrow, thin concave.

**Table 1** Measurements (in mm) of complete or nearly complete specimens of *Liothyrella labiata* sp. nov.

<table>
<thead>
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<th>Specimen</th>
<th>Length</th>
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<th>Depth</th>
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Dorsal valve. (From serial grinding) Loop short, ventrally arched anteriorly, diverges little, central between each valve.

Remarks

*Liothyrella* is known from the Oligocene to Recent. Numerous species have been described from Antarctica, southern South America, west coast of Central and South America, New Zealand and Australia (Cooper, 1983). Tertiary *Liothyrella* include *L. anderssoni* Owen and *L. lecta* (Guppy) (Owen 1980), *L. kakanuiensis* (Hutton), *L. circularis* Allan, *L. neglecta* (Hutton), *L. concentrica* (Hutton), *L. oamarntica* (Boehm), *L. thomsonii* Allan, *L. skinneri* Allan and *L. graveida* (Suess) (Allan, 1932), *L. gigantea* Allan (Allan, 1960) and a new species from the Cardabia Formation of the Carnarvon Basin. *L. labiata* differs from all of these species in that it has a distinctive sulciplicate anterior commissure. A new species of *Liothyrella* from the Late Cretaceous of both the Carnarvon and Perth Basins (Craig, 1999b) has a uniplicate anterior commissure. *L. pulchra* Thomson from the Late Eocene has a sulciplicate anterior commissure. It is overall more round (width 88% of shell length) and the foramen is larger (9% of shell length) compared to *L. labiata*. These features suggest a new taxon is in order. Richardson described the species in her unpublished thesis (1971) as *Gryphus labiata*. Her specimens included P17320-22 (Museum of Victoria) from the Tortachilla Limestone (Late Eocene), Maslin Bay, Aldinga in South Australia. The species does not belong to *Gryphus*, which is a Northern Hemisphere genus, due to morphological differences from the genus.

Etymology

Richardson, in her unpublished thesis, called the species *labiatus*. In honour of her work I maintain the name in part, due to the large lip on the beak.
Liothyrella bulbosa (Tate, 1880)
Figures 5, 9 E–H

1880 Terebratula bulbosa Tate: 145–146, plate 7, figures 5a–b.
1910 Terebratula bulbosa: Buckmann, 25, 26, plate 3, figure 7.
1910 Terebratula bulbosa: Lowry, 67, 86.

Material Examined
Eucla Basin: F6806/1, F6806/2–13, F6806/17, F6813/1–7, 2 km east of Wilson Bluff, 0–6 m below top of formation; F6810b and d, Wilson Bluff; F6851/1–7, Abrakurrie Cave; F6817/1–21, Abrakurrie Cave, 0–3.35 m below top of formation; F6830/1–2, Abrakurrie Cave, near top of formation; F6833, Mullamullang Cave; F6875/1–5, Toolinja Cove; F6812, Madura–13 km north of Firestick Cave; Wilson Bluff Limestone, Late Eocene.

Description
Exterior. Shell medium to large from 27 – 51 mm in length, ovate to subcircular. Biconvex, greatest depth at mid-length, dorsal valve from slightly flatter to as convex as ventral valve, depth 50–75% shell length. Width greatest at mid-length, width 86–93% shell length. Shell smooth; growth lines distinct; punctae very fine and dense. Cardinal margin gently curved, to 54% shell width; valves lateral edge sharply bevelled, lateral margin gently concave with respect to ventral valve except for anterior fifth where it rises strongly towards ventral valve; anterior valve edge sharply bevelled, anterior commissure unisulcate, sulcus gently to strongly pronounced, with corresponding keel in ventral valve of strongly pronounced specimens. Umbo short, beak truncated, erect; beak ridges sharp. Foramen permesothyrid, round, small with respect to shell length (to 3%) but fairly large when compared to other species. Symphytium

Figure 5 Liothyrella bulbosa (Tate, 1880). Serial section. Measurements indicate distance from last section in mm. Scale bar = 1 mm.
Table 2 Measurements (in mm) of Liothyrella bulbosa
(Tate, 1880).

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conca, obscured by foramen; palintrope wide, low and concave.


Dorsal valve. Sockets triangular; outer socket ridge narrow; inner socket ridge curved over socket, wide, joined to crural base with deep groove between them. No hinge plates observed. Crura divergent, thin, sharp. Cardinal process ranges from protuberant small cup to one with a swollen base. Rim with three vertical extensions, crown-like.

Remarks
This species originally placed in the genus Terebratula by Tate is known from the northern hemisphere. The Terebratula has numerous species in the southern hemisphere assigned to it until more detailed examination of the specimens led to the formation of numerous genera with similar loop characteristics and cardinalia. It is rejected as it is a northern hemisphere genus and L. bulbosa has characteristics more consistent with Liothyrella than Terebratula. These include the features of the loop, foramen and cardinalia, which best fit the general description for the genus Liothyrella. Liothyrella is a known southern hemisphere species. L. bulbosa differs to all prior described species because of its large size extending to over 48 mm in length, its large depth to length ratio, and ovate outline.

Foramen permesothyrid to epithyrid, small with labiate extension to foramen; beak ridges quite sharp. Foramen permesothyrid to epithyrid, small with labiate extension to foramen; beak ridges quite sharp. Foramen permesothyrid to epithyrid, small with labiate extension to foramen; beak ridges quite sharp. Foramen permesothyrid to epithyrid, small with labiate extension to foramen; beak ridges quite sharp.

L. bulbosa is recorded from Edinburgh, Yorke Peninsula (Tate, 1880) in deposits of Late Oligocene age and a glauconite bank, Cockburn Island, Antarctic Peninsula that Buckmann (1910) concludes as of Miocene age.

Liothyrella subcamea (Tate, 1880)
Figures 6, 9I-L.

1880 Terebratula subcamea Tate: 145, plate 9, figures 1a-b;

1899 Terebratula subcamea: Tate, 1899: 251;

1970 Terebratula subcamea: Lowry 67, 86.

Material Examined
Eucla Basin: F5541, Twilight Cove; F6113/5, Cockelbiddy Cave; F6808/1, F6808/2-3, F6809/1-7, F6809/8-9, F6814/1-10, Abrakurrie Cave; F6817/1-21, Abrakurrie Cave, 0-3.2 m below top of formation; F6811, Abrakurrie Cave, 3.4-3.7 m from top of formation; F6803, F6844, Abrakurrie Cave, 6.2-12.1 m below top of formation; F6804, Weebubbie Cave; F6807/1, F6807/2, F6845/1-5, Mullamullang Cave; F6805, F6806, F6823, F6825, 2 km east of Bluff; F6810, Wilson Bluff; F6875, Toolinna Cove; Wilson Bluff Limestone, Late Eocene.

WAM 68.350, Cliff face of Toolinna; F6812, Madura, 12.9 km north of Firestick Cave; Abrakurrie Limestone, Early Miocene.

Description
Exterior. Shell ovate to subcircular from 17-68 mm in length. Ventribiconvex with dorsal valve nearly flat, greatest depth posterior to mid-length, depth to 56% shell length. Width greatest at mid-length, width from 84% to 102% shell length. Shell smooth, growth lines distinct anteriorly, punctae very dense and very fine, oval in shape. Cardinal margin gently curved, dorsal umbo protuberant, margin to 60% shell width; valves lateral edge sharply bevelled, lateral margin straight; anterior valve edge sharply bevelled, anterior commissure rectimarginate. Umbo short; beak erect, labiate extension to foramen; beak ridges quite sharp.

Remarks
The large size of this species (up to 60 mm in length), the flatness of the dorsal valve and the high
ratio of width to length substantiate this species as different to all other recorded Liothyrella.

Superfamily Cancellothyroidea Thomson, 1926
Family Cancellothyrididae Thomson, 1926
Subfamily Cancellothyridinae Thomson, 1926
Genus *Murravia* Thomson, 1916

Type Species
*Terebratulina davidsoni* Etheridge = *Terebratulina cattinuliformis* Tate.

*Murravia triangularis* (Tate, 1880), comb. nov.

Figure 8 H–L

1880 *Terebratulina triangularis* Tate: 160, plate 7, figures 7a–7d.
1899 *Terebratulina triangularis*: Tate: 254.

Diagnosis
Dorsal valve nearly flat, crenulation within

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Table 3 Measurements (in mm) of *Liothyrella subcarnea* (Tate, 1880).

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Figure 6 *Liothyrella subcarnea* (Tate, 1880). Serial section. Measurements indicate distance from last section in mm.
Scale bar = 1 mm.
anterior margins of both valves, hypothyrid foramen, cardinal process small, strong.

Material Examined
WAM 88.372, Cliffs at eastern end of Israelite Bay, Toolinna Limestone, Late Eocene. F6836/1-3, Abrakurrie Cave; F6837, Weebubie Cave, 0–12.2 m below top of formation; F6831, 15.2 m below top of formation; WAM 68.324b, Murra-el-elevan Cave, Wilson Bluff Limestone, Late Eocene.

Description
Exterior. Small shell, 6.6 to 8.1 mm in length, triangular to subcircular. Ventribiconvex, dorsal valve nearly flat, depth to 32% shell length. Width at or near mid-length, 94–101% shell length. Shell costate, 6 ribs per mm at mid-length, ribs rounded, much wider than interstitial spaces, ribs bifurcate at umbo, strongly curved towards lateral margins; growth lines distinct, not prominent. Cardinal margin curved, narrow to 30% shell length; valve lateral edge bevelled, lateral margin nearly straight; valve anterior edge bevelled, anterior commissure unisulcate, sulcus nearly taking up entire width. Beak short to 12% shell length, triangular, suberect; beak ridges sharp. Foramen medium sized to 4% shell length, trapezoid to round; hypothyrid; deltoidal plates disjunct, short; palintrope narrow, concave.

Interior. Ventral valve. Hinge teeth rectangular,
edge narrowly triangular, cyromatodont, no buttressing on valve, no dental plates. Pedicle trough deep, width of valve with no thickening. Muscle scars indistinct. Some crenulations on inner margins.

Dorsal valve. Outer socket ridges wide; socket short, nearly flat. Inner socket ridge overhangs socket slightly, projecting over cardinal margin. Cardinal process slightly depressed, small, subcircular, posterior margin squared. No loop or muscle scars observed.

Remarks
This species was previously known as Terebratulina triangularis. The flat to concave dorsal valve, internal crenulations at the valve margins, hypothyrid foramen and strong cardinal process place it in the genus Murravia (Thomson, 1916). It is described from Blanche Point, Aldinga Cliffs and in the Bunda Cliffs, Great Australian Bight (Tate, 1880) and Castle Cove, Aire River district, Castle Cove Limestone, and Point Finders, Browns Creek Clays, Victoria (Richardson, unpublished thesis).

Genus Terebratulina d'Orbigny, 1847

Type Species
Antonia retusa Linné, 1758.

Terebratulina christopheri sp. nov.

Diagnosis
Small to medium sized Terebratulina, multicostate to 5 ribs per mm; foramen large, mesothyrid.

Material
Holotype
WAM 88.852 Nanarup Lime Quarry, Nanarup Limestone, Werillup Formation, Bremer Basin.

Paratypes
WAM 94.92 0.5 km west of Nanarup Lime Quarry, WAM 94.127, Nanarup Lime Quarry, Nanarup Limestone, Werillup Formation, Bremer Basin.

Other Material
Bremer Basin: WAM 67.215, 70.176, 75.38, 75.40, 76.81, 94.71 – 94.91, 94.93 – 94.124, 94.126, 94.170, UWA 37562, Nanarup Lime Quarry; WAM 94.93, 94.1337, 0.5 km west of Nanarup Lime Quarry; WAM 94.125, 94.805, Manypeaks Quarry, Nanarup Limestone, Werillup Formation, Bremer Basin.

WAM 67.72, 67.82, 69.200, 72.327, 78.4099, 82.3049, 82.3052 –3076, 83.2652, North Walpole, 26
Table 5  Measurements (in mm) of complete or nearly complete specimens of *Terebratulina christopheri* sp. nov.

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WAM 88.183, Booanya Well, Nanambinia Station, Toolinna Limestone, Late Eocene.

F6831, Wilson Bluff, 15.3 m below top of formation; F6850, Abrakurrie Cave, F6832, Wilson Bluff Limestone, Late Eocene.

Description

**Exterior.** Shell pyriform to subpentagonal, small to medium, 3.6 to 24 mm long. Biconvex, both valves equally so, depth to 50% shell length. Width to 81% shell length, widest anterior to mid-length. Finely and densely punctate. Costellate, 5 ribs per mm, ribs same width as trenches, rounded, bifurcate over entire length; numerous growth lines. Cardinal margin strongly curved to triangular, acute, to 64% shell width; valves lateral edge bevelled, lateral margin straight to sigmoidal (curved upwards to dorsal valve posteriorly, down towards ventral valve centrally and up towards dorsal valve anteriorly); anterior commissure uniplicate, plication to 65% shell width. Umbo truncated; bead sub erect; bead ridges attrite. Foramen medium to large, to 7.5% shell length, round, mesothyrid.

**Deltidial plates** small, disjunct, with lateral ridges.

**Interior.** Ventral valve. Hinge teeth small, rectangular, pointed posteriorly (cyrtomatodont), groove with cardinal margin, no plates, no buttressing. Muscle scar indistinct, elongate.

Dorsal valve. Outer socket ridge thin; socket an elongate groove; inner socket ridge and outer hinge plate both fused to crural base, thin, folding over socket posteriorly producing "wings" which extend beyond cardinal margin. Crura convergent to loop, loop offset ring, transverse band with depressed arch. Cardinal process small striated cup between inner socket ridge wings.

Remarks

Small (less than 5 mm in length) specimens from the Pallinup Siltstone have relatively larger foramen (to 40% shell length) compared with small specimens (less than 5 mm) from the Nanarup Limestone (to 10% shell length).

Australian Tertiary *Terebratulina* have been generally confused taxonomically. *T. sculati* (Tate, 1880), and *T. flindersi* Chapman, 1913 are *Cancellothyris* species due to their conjunct deltidial plates. *T. lenticularis* Tate, 1880 and *T. triangularis* Tate, 1880 are species of *Murravia* as they have a hypothyrid foramen and hinge plates. *T. suessi* Allan, 1932 and *T. ellisoni* Allan, 1932 are both described as having large submesothyrid foramen. The foramen of *T. christopheri*, although large, is mesothyrid. A new *Terebratulina* species (Craig, 1999b) from the Late Cretaceous of the Carnarvon Basin has 6 ribs per mm, bifurcation occurs anterior to the umbo and the foramen is submesothyrid. In *T. christopheri* there are 5 ribs per mm, bifurcation begins at the umbo and the foramen is mesothyrid.
Cenozoic Brachiopoda of the Bremer and Eucla Basins

T. christopheri differs from a new Terebratulina species from the Wadera Calcarenite (Late Paleocene), Cardabia Formation, Carnarvon Basin (Craig, 2000), which bifurcates anterior to the mid-length and has 4 ribs per mm.

Etymology
The species is named in honour of Dr Christopher J. S. De Silva, research associate at the University of Western Australia.

Suborder Terebratellidina Muir-Wood, 1955
Superfamily Terebratellioidea King, 1850
Family Laqueidae Thomson, 1927
Genus Aldingia Thomson, 1916
Type Species Terebratella furculifera Tate, 1880.

Aldingia furculifera (Tate, 1880)

1880 Terebratella furculifera Tate: 161, plate 11 figures 7a-c.
1880 Waldheimia (?) insolita: Tate: 151–152.
1899 Terebratella furculifera: Tate: 254–255.

Material Examined
Bremer Basin: WAM 94.147–152, 95.443, Manypeaks Lime Quarry; WAM 94.165, Nanarup Lime Quarry; WAM 95.63, 437, Nanarup off Mount Richard Road, Paul Terry Land Lot 3195; Nanarup Limestone, Bremer Basin.
WAM 82.3050, 51, Walpole North, Pallinup Siltstone, Bremer Basin.
Eucla Basin: WAM 88.370, Start of cliffs at east side of Israelite Bay, Toolinna Limestone, Late Eocene.

Description
Exterior. Shell ovate to subcircular, medium-sized to 6.6 to 33.6 mm long. Biconvex, dorsal valve flatter in some specimens, depth to 55% shell length. Width greatest at mid-length to 100% shell length. Smooth, growth lines fine, very fine and dense punctae. Cardinal margin to 50% shell width, strongly curved; valves lateral edge bevelled, lateral margin gently sigmoidal; anterior valve edge bevelled, anterior commissure rectimarginate. Umbo strong, beak erect to slightly incurved; beak ridges rounded. Foramen large to 10% shell length, round, submesothyrid; deltidial plates conjunct in most cases. Symphytium low, narrow, slightly convex.

Interior. Ventral valve. Hinge teeth relatively small, triangular (deltidiodont) with curve to the posterior; swollen bases to margin and in some cases to valve floor. Pedicle trough fairly narrow. Median ridge developed from base of trough and extending to mid-length. Elongate muscle scars either side of ridge.

Dorsal valve: Outer socket ridge narrow. Socket triangular with posterior roof, floor swollen to lateral margin. Inner socket ridge curved over socket, base slightly swollen. Crura divergent, bases fused to inner socket ridge, slightly swollen. Hinge trough formed from union of inner hinge plates.
Table 6 Measurements (in mm) of complete or nearly complete specimens of *Aldingia furculifera* (Tate, 1880).

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Remarks

*Aldingia furculifera* has been described from the Tortachilla Limestone (Eocene) and the Blanche Point Marl (Eocene), Maslin Bay, and Christies Beach, Aldinga, South Australia, the Wilson Bluff Limestone (Late Eocene), Bunda Cliffs, Great Australian Bight, Western Australia, the Browns Clay Limestone (Eocene), Aire, Johanna River, the Castle Cove Limestone (Eocene), Aire, the Aire Clay (Eocene), Aire and the Calder River Limestone Aire coast, Glen Aire in Victoria (Richardson, 1973a). Chapman and Crespin (1934) describe *Terebratula aldingae* from the Plantagenet Beds, Norseman, Western Australia. It is most likely to be this species, although the description is very brief.

Family Terebratellidae King, 1850

Subfamily Terebratellinae King, 1850

Genus *Austrothyris* Allan, 1939

Type Species

*Waldheimia gambierensis* Thomson, 1918.

*Austrothyris grandis* (Tate, 1880)

Figure 15 J–K

1865 *Waldheimia grandis* Tenison-Woods: 2, figure 1.

1876 *Waldheimia gambierensis*: Etheridge: 19, plate 2, figures 4a–d.

1880 *Waldheimia grandis*: Tate: 152, plate 11, figures 3 and 4.

1927 *Magellania grandis*: Crespin and Chapman in Thomson: 301


1999 *Austrothyris grandis*: Craig: 456–458, figure 4A–F.

Material Examined

F6109/4, Madura – 12.8 km North Cave; WAM 62.158, Swallow Cave, Cocklebiddy Station; Wilson Bluff Limestone, Late Eocene.

Description

Exterior. Dorsal valve only. Convex, ovate, connects with bifurcating median septum. Median septum blade-like, higher posteriorly than anteriorly, extends to mid-length or just posterior to it. Cardinal process incipiently raised triangular posteriorly located in hinge trough. Serial grinding indicates teloform (magellaniiform) type loop, extends to mid-length.
multiplicate anteriorly. Growth lines distinct, ovate punctae fine and dense. Cardinal margin curved; valves lateral edge rounded, lateral margin straight or nearly so, incomplete; anterior edge roundedly crenulate, anterior commissure rectimarginate, incomplete.

**Interior.** Interior unavailable due to matrix. Median septum partially visible on weathered specimen, extends to mid-length, blade-like, no swollen base anteriorly, thickens posteriorly.

**Remarks**

Although only two partial brachial valves were available for identification, the size, plication and straight lateral and anterior margins are quite distinctive.

The species is recorded from Mount Gambier and the Murray River cliffs of South Australia (Allan, 1939). It is found in deposits of Early Miocene age. This is the earliest record of the species in Australia.

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**Genus Diedrothyris** Richardson, 1980

**Type Species**

*Waldheimia (?) johnstoniana* Tate, 1880.

**Diedrothyris johnstoniana** (Tate, 1880)  
Figure 11 A-D

1880 *Waldheimia (?) johnstoniana* Tate: 151, plate 8, figure 9a-b.

1880 *Waldheimia (?) fimbriata*: Tate: 150-151, plate 8, figure 2a-b.

1899 *Magellania johnstoniana* Tate: 253.

1899 *Magellania (?) fimbriata*: Tate: 252.


1980 *Diedrothyris johnstoniana*; Richardson: 49, plate 11, figure 9-16.

**Material Examined**

WAM 74.42, 94.142-145, Nanarup Lime Quarry, Nanarup; WAM 95. 438, Nanarup off Mount Richard Road, Paul Terry Land, Lot 3195; Nanarup; WAM 94.161, Manypeaks Lime Quarry; Nanarup Limestone, Bremer Basin.
Description

**Exterior.** Medium sized shell to 25.7 mm long. Oval to subcircular, widest at mid-length, width to 77% shell length. Biconvex, both valves nearly equal, depth greatest at mid-length, depth to 53% shell length. Shell plicate, plicae extending from umbo, more pronounced centrally, growth lines numerous, distinct, finely and densely punctate, punctae ovate. Strong double fold in centre of keel on ventral valve. Cardinal margin curved, to 60% shell width; valves lateral edge gently bevelled, lateral margin with slight sigmoidal curve, crenulate from just posterior to mid-length; anterior commissure unisulcate, crenulate (multiply). Umbo strong, truncate; beak suberect, thin lip present; beak ridges gently rounded. Foramen medium to large to 6.5% of shell length, mesothyrid. Deltidial plates conjunct, symphytium wide, concave with swollen mid-section.

Remarks

Richardson (1980) describes the species from Late Oligocene to Middle Miocene deposits in Victoria and Tasmania. This is the earliest record of the species and the only record from Western Australia.

Genus *Victorithyris* Allan, 1940

**Type Species**

*Victorithyris peterboroughensis* Allan, 1940.

*Victorithyris divaricata* (Tate, 1880)

Figure 10 A-D

1880 *Waldheimia* (?) *divaricata* Tate: 149, plate 8, figures 8a-b.


1980 *Victorithyris divaricata*: Richardson: 47-48, plate 10, figure 16.

Material Examined

F5542/1, Twilight Cove; F6111/2, Murra-el-elevyn Cave; Wilson Bluff Limestone, Middle Eocene. F6857, Tommy Graham’s Cave, 30.5-36.6 m below surface, Abrakurrie Limestone, Early Miocene.

Description

**External.** Medium-sized ovate to sub-circular shell, 15.7 to 23.3 mm long. Biconvex, greatest depth

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at mid-length, depth to 64% shell length. Width greatest at mid-length, width to 87% shell length. Shell finely and densely punctate, growth lines prominent especially anteriorly; plicate, two ribs per mm at mid-length, plicae triangularly rounded. Cardinal margin curved, to 74% shell width; valves lateral edge rounded to impressed, lateral margin straight, crenulate; anterior valve edge rounded to flat, anterior commissure unisulcate, crenulate. Umbo stout, suberect, thin lip present; beak ridges rounded. Foramen medium-sized, 3.7% shell length, mesothyrid. Deltidial plates conjunct, symphytium wide, concave with swollen mid-section.

Remarks

*Victorithyris divaricata* is described from the Mannum Formation of Early Miocene age in South Australia (Richardson, 1980). This is the earliest record of the species and the only record from Western Australia.

*Victorithyris garibaldiana* (Davidson, 1862)

Figure 10 E-K

1833 *Terebratula* sp. Sturt: 254, plate 3, figure 15
1862 *Waldheimia garibaldiana* Davidson: 446, plate 24, figure 9.
1865 *Waldheimia imbricata* Tenison-Woods: 2, figures 3a-b.
1876 *Waldheimia garibaldiana*: Etheridge: 17,18, plate 1, figures 2a-b.
1880 *Waldheimia garibaldiana*: Tate: 146-148, plate 11, figures 1a-c.
1899 *Magellania garibaldiana*: Tate: plate 252.

Table 10 Measurements (in mm) of Victorithyris garibaldiana (Davidson, 1862).

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<td>9.0</td>
</tr>
<tr>
<td>F6856/1-2</td>
<td>17.3</td>
<td>13.2</td>
<td>9.5</td>
</tr>
</tbody>
</table>


Material Examined

**Eucla Basin:** WAM 68.1424, F6856/1-2, Mullumullang Cave; F 6108/5, Malcolm Scarp, 12.3 – 15.4 m below plain; F6109/3, F6846, F6847, F6852-55 Madura, 12.9 km north of Firestick Cave; F6110/3, Madura, 9.6 km, South Cave; F6111/1, 6, Murra-el-elevyn Cave; F6113/2 Cocklebiddy Cave; F6848, Abrakurrie Cave; Wilson Bluff Limestone, Late Eocene.

Description

External. Small to medium-sized shell from 7.9 to 25 mm long; ovate to subcircular. Ventrilocconvex; depth greatest at mid-length, depth to 66% shell length. Widest slightly posterior to mid-length; width to 89% shell length. Shell multiply, plicate arising shallowly posterior to umbo, deepening anteriorly and antero-laterally; width of interstitial spaces variable; plicae rounded; shallow sulcus in dorsal valve of some specimens; finely and densely plicate, plicae egg shaped, widest anteriorly; growth lines numerous and distinct. Cardinal margin gently to strongly curved, ventral umbo prominent in some specimens, width to 90% shell width; valves lateral edge rounded, lateral margin straight to anterior then curved towards ventral valve, crenulate anterior to mid-length; valves anterior edge rounded, anterior commissure unisulcate, sulcus shallow to deep, narrow (33% shell width) to wide (62% shell width); crenulate. Umbro stout, truncate, beak suberect, with slight lip; beak ridges rounded. Foramen medium-sized to 5% shell length, mesothyrid. Deltoidal plates conjunct, symphytium medium width and depth, grooved, convex within groove margins; palintrope narrow.

Internal. Outer socket ridges thin marginally, swollen under socket. Socket triangular, floor curved, no roof. Inner socket ridge swollen, fused to outer hinge plate and crural bases in some specimens. Swollen bases protuberant over cardinal margin. Crural bases thickened posteriorly, not swollen. Inner hinge plates small, united to form shallow trough. Median septum blade-like, extends to anterior to mid-length, base thickens posteriorly and again anteriorly. Cardinal process small protuberant striated depressed “dish” within swollen bases of cardinalia, swollen boss under process. Loop incomplete, transverse bands appear to connect to median septum anteriorly. Muscle scars in sunken floor anterior to cardinal area, sharp posteriorly widening into ovate depressions.

Remarks

Richardson (1980) described Victorithyris garibaldiana from early to late Miocene deposits in South Australia, Tasmania and Victoria. This is the earliest record of the species and the first from Western Australia.

Victorithyris tateana (Tate, 1880)

**Figure 10 L-P**

1880 Waldheimia tateana Tate: 150, plate 7, figures 6a-b, plate 8, figures 6a-c, plate 9, figure 2.
1899 Magellania tateana: Tate: 233.

Material Examined

**Bremer Basin:** WAM 76.82, 67.214, 94.156, 94.164, 95.441 Nanarup Lime Quarry, Nanarup, Nanarup Limestone, Bremer Basin.
Table 11  Measurements (in mm) of complete or nearly complete specimens of Victorithyris tateana  (Tate, 1880).

<table>
<thead>
<tr>
<th>Specimen</th>
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<th>Depth</th>
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<td>7.1</td>
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<td>WAM 76.82</td>
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<tr>
<td>WAM 94.156</td>
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<td>–</td>
</tr>
<tr>
<td>WAM 94.164</td>
<td>incomplete 14.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>WAM 95.441</td>
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<td>11.5</td>
<td>–</td>
</tr>
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<td>WAM 88.184</td>
<td>15.7</td>
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<td>WAM 88.184</td>
<td>16.1</td>
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<td>F6112/11</td>
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<td>10.6</td>
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<tr>
<td>F6114/12</td>
<td>14.0</td>
<td>11.6</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Eucla Basin: WAM 88.184, Booanya Well, Nanambinia Station, Toolinna Limestone, Late Eocene.

F6108/2, F6108/3, Scarp, 9.2-12.2 m below plain; F6110/1, WAM 62.51, Cave 10 km south of Madura; F6112/3, F6112/8, F6112/9, Toolinna; F6112/3, Toolinna, 0-74.7 m above sea level; F6112/12, Toolinna, 0-74.7 m above sea level; F6114/4, Haig Cave, immediately below formation; F6814, Abrakurrie Cave, 23-26 m below to of formation; F6849, Wilson Bluff; WAM 66.1418, Madura, 13 km North Cave; Wilson Bluff Limestone, Late Eocene.

F6869/1-8, 10 km north of Firestick Cave, 6-9 m below top of formation, Abrakurrie Limestone, Early Miocene.

Description

Exterior. Elongate oval 10 to 25 mm long. Biconvex, depth greatest posterior to mid-length to 59% shell length. Narrow, greatest width near mid-length, width to 80% shell length. Shell smooth, growth lines distinct, finely and densely punctate. Cardinal margin strongly curved; lateral valve edges rounded, lateral margin nearly straight to slightly curved to ventral valve posteriorly; anterior valve edge gently rounded, anterior commissure rectimarginate. Umbo strong, beak suberect; beak ridges rounded. Foramen round 4% to 6% shell length, mesothyrid; deltoidal plates conjunct. Symphytium high in small to low in larger specimens, narrow, convex.


Remarks

Victorithyris tateana is described from the Tortachilla Limestone (Late Eocene), Maslin Bay, Aldinga, from Port Noarlunga and Stansbury, Yorke Peninsula in South Australia as well as Castle Cove Limestone (Late Eocene – Early Oligocene), Calder River Limestone and the Glen Aire Clays in Victoria (Richardson, 1980). Chapman and Crespin (1934) described a specimen of this species from the Plantagenet Beds, Albany, Western Australia.

Genus Neothyris Douville, 1879

Type Species

Terebratula lenticularis Deshayes, 1839.

Neothyris rylandae Craig, 1999

Figures 13 G–J, 14 A–C.

1999 Neothyris rylandae Craig; 267–275, figures 3 A–F, 4 A–C.

Material Examined

Holotype

WAM 82.2368; Roe Plains, Madura district, Western Australia, Pit 1.5 km N of Hampton Microwave Repeater Tower. Basal 0.4 m carbonate sand.

Paratypes

WAM 69.382; Roe Plain, 25 miles east of Madura south side of Eyre Highway. Bulldozed pit approx. 3 m deep.
Cenozoic Brachiopoda of the Bremer and Eucla Basins

WAM 75.178, WAM 76.2480; Roe Plain, Eucla Basin, Quarries beside road from Eyre Highway to Hampton Microwave Tower.

WAM 82.2367, 82.2369, 82.2370, 82.2372, 82.2373, 82.2378; Roe Plains, Madura district, W. A. Pit 0.5 km N of Hampton Microwave Repeater Tower. Basal 0.6 m carbonate sand.

WAM 85.2026, 82.2374, 82.2376, 82.2377, 82.2379 - 82.2388; Roe Plains, Madura district, W. A., Pit 1.5 km N of Hampton Microwave Repeater Tower; spoil heaps near base of tower.

Remarks
The material above is fully described in Craig, (1999a). There is no revision to the original descriptions.

Subfamily Stethothyridinae
MacKinnon, Beus and Lee, 1993

Genus Stethothyris Thompson, 1918

Type Species
Stethothyris uttleyi Thompson, 1918.

Remarks
Allan (1940) suggested that Australian species placed in the genus Stethothyris were actually Victorithyris. Richardson (1980) reinstated Stethothyris based on the studies of the growth stages. MacKinnon et al. (1993) considered the name Stethothyris acceptable. Hiller and MacKinnon (in press) consider that the "more elaborate cardinal process, more strongly incurved beak, greater overall inflation of the valves and more elaborate commissure folding" place Stethothyris pectoralis in the new genus.

Stethothyris pectoralis (Tate, 1880)
Figures 7, 11 H-M, 12 A-C

1880 Waldheimia pectoralis Tate: 157, plate VII, figures 1a-d.
1899 Magellania pectoralis: Tate: 253.
1918 Stethothyris pectoralis: Thomson: 25, plate XVII, figure 60.
1940 Victorithyris pectoralis: Allan: 292, plate XXXV, figure 3.
1996 Stethothyris pectoralis: Brunton et al.: figure 16 A and B.

Material
Bremer Basin: WAM 67.201, 67.213, 69.231, 70.175, 94.132 – 141, 94.167, 99.312 Nanarup Lime Quarry; WAM 94.128 – 94.131, 95.439 0.5 km west of Nanarup Lime Quarry; WAM 95.602, 95.603 Manypeaks Quarry; Nanarup Limestone, Werillup Formation, Bremer Basin.

Eucla Basin: F6113/1, Cockelbiddy Cave, 44.2–70.2 m below top of formation, F6809/8–9, F6814/1–10, Abrakurrie Cave; F6817/1–21, Abrakurrie Cave, 0–3.4 m below to of formation; F6811/1–2, Abrakurrie Cave, 3.4–6.4 m below top of formation; F6816, Abrakurrie Cave, 24.4–27.5 m below top of formation; F6810, Wilson Bluff; Wilson Bluff Limestone, Late Eocene.

Description
Exterior. Shell subcircular; medium to large to 62.9 mm long. Ventriconvex, depth to 79% shell length. Width to 87% shell length, widest at mid-length. Finely and densely punctate, growth lines numerous, distinct, sulcus in dorsal valve from dorsal umbo divergent to anterior commissure, keel in ventral valve from ventral umbo. Cardinal margin curved, to 42% shell width; valves lateral edge bevelled, lateral margin convex with respect to dorsal valve; anterior commissure unisulcate, sulcus to 60% shell width. Umbo stout, suberect to erect; beak ridges attrite. Foramen small, 2% shell length, round, permesothyrid; deltidial plates conjunct. Symphytium, striated longitudinally, raised under beak, concave either side of raised area, takes up majority of interarea.


Dorsal valve. Outer socket ridge as thick as margin; socket small, triangular. Inner socket ridge overhangs socket posteriorly, swollen, fused to outer hinge plate and crural base; slight groove between inner socket ridge and outer hinge plate. Crural base swollen posteriorly. Inner hinge plates fused, transect centre of cardinal area, narrow, extend to upper platform on median septum, posterior extension to cardinal process. Median septum short, low, blade-like, rises, base swells posteriorly, fused to hinge platform. Muscle scars shallow elongate trenches either side of septum. Cardinal process small deep rimmed trilobed cup.

Remarks
This species is described from Eocene Tortachilla Limestone, Blanche Point Cliff, Aldinga and Happy
Cenozoic Brachiopoda of the Bremer and Eucla Basins

Table 12 Measurements (in mm) of complete or nearly complete specimens of *Stethothyris pectoralis* (Tate, 1880).

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Length</th>
<th>Width</th>
<th>Depth</th>
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</thead>
<tbody>
<tr>
<td>WAM 67.201</td>
<td>-</td>
<td>37.9</td>
<td>28.3</td>
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<tr>
<td>WAM 69.231a</td>
<td>35.8</td>
<td>-</td>
<td>31</td>
</tr>
<tr>
<td>WAM 69.231b</td>
<td>-</td>
<td>32.2</td>
<td>19.7</td>
</tr>
<tr>
<td>WAM 70.175</td>
<td>-</td>
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<td>27.3</td>
</tr>
<tr>
<td>WAM 94.128</td>
<td>44.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>WAM 94.129</td>
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<td>39.9</td>
<td>28.0</td>
</tr>
<tr>
<td>WAM 94.133</td>
<td>-</td>
<td>34.5</td>
<td>-</td>
</tr>
<tr>
<td>WAM 94.138</td>
<td>43.1</td>
<td>32</td>
<td>26.6</td>
</tr>
<tr>
<td>WAM 99.312</td>
<td>44.4</td>
<td>38.3</td>
<td>19.7</td>
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<tr>
<td>UWA 16660</td>
<td>38.2</td>
<td>34.4</td>
<td>-</td>
</tr>
<tr>
<td>F68811/1-2</td>
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<td>(part only)</td>
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</tr>
<tr>
<td>F6814/1-10</td>
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<td>-</td>
<td>-</td>
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<td>36.1</td>
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<tr>
<td>F6816</td>
<td>44.4</td>
<td>30.9</td>
<td>27.5</td>
</tr>
</tbody>
</table>

Table 13 Measurements (in mm) of *Stethothyris sufflata* (Tate, 1880).

<table>
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<th>Specimen</th>
<th>Length</th>
<th>Width</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>F6829</td>
<td>47.1</td>
<td>38.9</td>
<td>31.0</td>
</tr>
</tbody>
</table>

Remarks

*Stethothyris sufflata* is described from the Tertiary deposits of the Yorke Peninsula (Late Eocene – Early Oligocene) (Tate, 1880; Allan, 1940), and Aldinga Bay which is possibly Tortachilla Limestone (Late Eocene) (Tate, 1880), South Australia.

Stethothyris tapirina (Hutton, 1873)

*Figure 13 A-F*

1873 *Waldheimia tapirina* Hutton: 36.

1905 *Bouchardia tapirina*: Hutton: 480, plate XLVI, figure 6.

1960 *Stethothyris tapirina*: Allan: 239, 266.

1993 *Stethothyris tapirina*: MacKinnon et al.: 343, figure 10 [15-21].

Remarks

In their reappraisal of the systematics of the *Stethothyris* group, Hiller and MacKinnon (in press) place *S. tapirina* in the genus *Alliquantula*.

Material Examined

**Bremer Basin:** WAM 94.155, 95.602, 99.313–316, Manypeaks Quarry, Nanarup Limestone, Werilup Formation, Bremer Basin.

**Eucla Basin:** F6809/1–7, F6821, Abrakurrie Cave; F6820/1–7, Wilson Bluff; Wilson Bluff Limestone, Late Eocene.

Description

Exterior. Shell subcircular; small to large, 14 to 42.5 mm long. Biconvex, ventral valve with slight keel; depth to 52% shell length. Width to 101% shell length, widest at mid-length. Valves smooth, numerous small growth lines, finely and densely punctate. Cardinal margin wide to lateral margin, curved; lateral margin edge bevelled to slightly impressed posteriorly, margin sigmoidal; anterior valve edge bevelled, anterior commissure unisulcate. Umbo strong, beak erect to incurved;

Figure 12  A-C, Stethothyris pectoralis (Tate, 1880). A, WAM 94.140, ventral valve interior x 2. B, WAM 99.334, ventral valve interior x 2. C, WAM 95.603, dorsal valve interior x 3. D-F, Stethothyris sufflata (Tate, 1880). D, E, F6829. D, dorsal valve exterior x 1.5; E, lateral margin x 2. F, F6831, dorsal valve interior x 2.5.
Cenozoic Brachiopoda of the Bremer and Eucla Basins

Table 14 Measurements (in mm) of *Stethothyris tapirina* (Hutton, 1873).

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Length</th>
<th>Width</th>
<th>Depth</th>
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<td>WAM 99.313a</td>
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<td>37.0</td>
<td>18.0</td>
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<td>WAM 99.313b</td>
<td>14.1</td>
<td>12.7</td>
<td>5.6</td>
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<tr>
<td>WAM 99.314</td>
<td>42.5</td>
<td>-</td>
<td>-</td>
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<tr>
<td>WAM 99.315</td>
<td>44.0</td>
<td>42.3</td>
<td>23.0</td>
</tr>
</tbody>
</table>

beak ridges sharp, extend to lateral margin. Foramen small, 1% shell length in large specimens, mesothyrid; deltidial plates conjunct. Symphytium wide, high, concave.


**Remarks**

The cardinal area was broken in the only specimen with an internal view available. It was observed that the area under the sockets, cardinal process and centre of the thickened section of the median septum was hollow.

*Stethothyris tapirina* (Hutton, 1873) is described from Oligocene deposits in New Zealand (Hutton, 1873, 1905; Allan, 1960, MacKinnon et al., 1993) including the Cobden Limestone Quarry, Greymouth, Westland and the Kokoamu Greensand, North Otago. Hiller and MacKinnon (in press) redescribe the species as *Aliquantula tapirina*. It is clear that the specimens from the Nanarup Limestone correspond well with the description of the this species. This is the earliest record of the species and the first record from Australia.

Subfamily Anakineticinae Richardson, 1991

Genus *Anakineta* Richardson, 1987

Type Species

*Terebratella cumingii* Davidson, 1852.

*Anakineta breva* Richardson, 1991

Figure 14 D-I

1880 *Magasella compta* Tate: 162–163, plate 10, figure 6a–e.


**Material Examined**

F6862/1–14, F6864/1–10, F6865/1–5, F6866/1–2, F6868/1–5, Firestick Cave, Abrakurrie Limestone, Early Miocene.

**Description**

*Exterior*. Shell small, 8–17.4 mm, ovate, greatest width at or near mid-length, width to 88% shell length. Ventribiconvex, ventral valve carinate, dorsal valve with shallow sulcus, depth to 62% shell length; shell smooth, very finely densely punctate, growth lines distinct, not prominent; cardinal margin curved, to 75% shell width; valves lateral edge rounded, lateral margin sigmoidal from cardinal to anterior margins; anterior valve edge bevelled, anterior commissure unisulcate, sulcus shallow, to 40% shell width; beak truncated, suberect, umbo labiate; beak ridges rounded anteriorly, sharp posteriorly; foramen small, 3.5% shell length, mesothyroid to permesothyrid; symphytium with thickened ridge centrally, striated horizontally, low, wide, concave; palintrope narrow.

*Internal*. Ventral valve. Hinge teeth triangular (deltidiodont), thick with slightly swollen bases, pointing anteriorly; pedicle opening narrow, narrow trough anteriorly; posterior area thickened; muscle scars unclear.

Dorsal valve. Sockets wide, floor swollen, no roof; inner socket ridges, outer hinge plate and crural base fused, swollen, posterior overhangs cardinal margin; crura short, rounded; median septum relatively thick posteriorly, bifurcates posteriorly under cardinal process, extend to mid-length; loop

Table 15 Measurements (in mm) of *Anakineta breva* Richardson 1991.

<table>
<thead>
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<th>Specimen</th>
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<th>Width</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
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<td>–</td>
</tr>
<tr>
<td>F6864/1–10</td>
<td>9.9</td>
<td>8.2</td>
<td>–</td>
</tr>
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<td>F6865/1–5</td>
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<td>12.3</td>
<td>6.2</td>
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<td>5.0</td>
</tr>
<tr>
<td>F6868/1–5</td>
<td>17.4</td>
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<td>8.0</td>
</tr>
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<td>9.2</td>
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<tr>
<td>F6868/1–5</td>
<td>11.1</td>
<td>–</td>
<td>8.3</td>
</tr>
<tr>
<td>F6868/1–5</td>
<td>10.8</td>
<td>9.0</td>
<td>8.2</td>
</tr>
</tbody>
</table>
trabecular, connecting bands widening distally; cardinal process a cup, lateral walls straight, extending inwards in a series of narrowing sections, anterior wall square, short ridge extends anteriorly to end of inner hinge plates, interior of process striated; muscle scars half moon shaped either side of median septum.

Remarks
The specimens accord well with Richardson's (1991) description and figures. Richardson describes the cardinal margin as straight. Specimens examined herein varied from gently curved to nearly straight. The species is recorded (Richardson, 1991) from the Point Addis Limestone (Janjukian, Upper Oligocene), Aireys Inlet, Victoria, Mannum Formation, Fyansford Formation, Puebla Formation and the Scutellina Limestone, all of Early Miocene age from South Australia.

Genus *Aliquantula* Richardson, 1991

Type Species
*Waldheimia (?) insolita* Tate, 1880.

Remarks
Hiller and MacKinnon (in press) place the genus *Aliquantula* in the subfamily Stethothyridinae because it differs from other Anakineticinae in that the hinge trough is excavated in juveniles, the posterior end of the septum bifurcates and the foramen is permesothyrid.

*Aliquantula insolita* (Tate, 1880)  
Figure 14 J-O

1880 *Waldheimia (?) insolita* Tate: 151–152, plate 9, figure 6b.

1899 *Magellania insolita*: Tate: 282.


Material Examined

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Length</th>
<th>Width</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
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<tr>
<td>WAM 76.15b</td>
<td>16.6</td>
<td>–</td>
<td>6.4</td>
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<tr>
<td>WAM 94.146</td>
<td>18.9</td>
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<td>8.2</td>
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<td>F6834</td>
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<td>5.8</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Cenozoic Brachiopoda of the Bremer and Eucla Basins


Remarks

Aliquantula insolita is described from the Tortachilla Limestone (Eocene) and the Blanche Point Marl (Eocene), Maslin Bay, Aldinga South Australia as well as the Browns Creek Clay (Eocene), Aire River District and the Castle Cove Limestone (Early Oligocene), Castle Cove at the mouth of the Johanna River of Victoria (Richardson, 1991). Chapman and Crespin (1934) describe a specimen of this species from the Plantagenet Beds, Norseman, Western Australia.

Genus Magadinella Thomson, 1915

Type Species

Magadinella woodsiana Tate, 1880.

Magadinella woodsiana (Tate, 1880)

1880 Magasella woodsiana Tate: 163–164, plate 10, figure 3a–d.


1899 Magasella woodsiana: Tate: 256–257.

1915 Magadinella woodsiana: Thomson: 400–4002, figure 13a–c.


1991 Magadinella woodsiana: Richardson: 36, figure 3A–F.

Material Examined

Bremer Basin: WAM 94.146, Nanarup Lime Quarry, Nanarup Limestone, Bremer Basin.

Eucla Basin: F6858/1–6, F6859/1–5, Tommy Graham’s Cave; F6862/1–14, F6863/1–10, F6864/1–10, F6865/1–5, F6867/1–11, F6869/1–8, Madura 12.9 km north of Firestick Cave; F6870/1–4, Thylacine Hole, 0–12.2 m below top of formation; Abrakurrie Limestone, Early Miocene.

F6860/1–9, Mullahmullang Cave, alluvium from Abrakurrie Limestone, Early Miocene.

WAM 62.161, Cocklebiddy Station, Nullarbor Plain.

Description

Exterior. Shell ovate, mid-sized, 8.8 to 24.2 mm in length. Biconvex shell, depth to 65% of shell length. Width greatest at mid-length, to 91% shell length, most to 75% shell length. Surface smooth, growth lines distinct, numerous, not prominent, punctae very fine and dense, ventral valve slightly carinate. Cardinal margin gently curved to 50% shell width; valves lateral edge bevelled to rounded in more elongate specimens, margin straight; anterior valve edge bevelled, anterior commissure gently to strongly unisulcate. Umbo truncated, beak suberect; beak ridges rounded. Foramen permosothyrid to mesothyrid, round, medium sized to 5% shell length, slightly labiate, lip divided in some specimens. Symphytium high, wide, thick ridge centrally, concave either side. Palintrope very narrow.


Dorsal valve. Cardinal area very swollen, high above septum. Sockets shallow troughs, outer socket ridge wide, inner socket ridge high, swollen overhanging socket posteriorly. Inner socket ridge, outer hinge plates and crura bases, indistinct from each other, swollen; inner hinge plates form narrow trough. Crura straight narrow bands. Medium septum extends beyond mid-length, anterior blade like, swallows to valve floor; posterior swollen, blade-like upper surface. Cardinal process rectangular cup, open posteriorly, encroached by swollen socket ridges laterally, shallow triangle interiorly with posterior apex, swollen protuberant “knob” anteriorly. Muscle scars in deep elongated trough either side of septum.

Remarks

Magadinella woodsiana has been described from the Mount Gambier Limestone (Late Oligocene), Mount Gambier, South Australia and the Calder River Limestone (Late Oligocene), Aire coast, Point Addis Limestone, (Late Oligocene), Kawarren and the Sandford Limestone (Late Oligocene), Sandford in Victoria (Richardson, 1991). The Nanarup Limestone specimens are the oldest record of the species in Australia.
Comparison of brachiopods (Table 18) from the Nanarup Limestone (Late Eocene) and the Wilson Bluff Limestone (Middle to Late Eocene) indicates 8 species in common between the two formations. These are Aldinga furculifera (Tate, 1880), Aliquantula insolita (Tate, 1880), Liothyrella liniata sp. nov., Magadinella woodsiana (Tate, 1880), Stethothyris pectoralis (Tate, 1880), Stethothyris tapirina (Hutton, 1873), Terebratulina
christopheri sp. nov. and Victorithyris tateana (Tate, 1880).

Two brachiopods found in the Nanarup Limestone are not present in the Wilson Bluff Limestone. These are Diedrothyris johnstoniana (Tate, 1880) and Westralicrania zenobiae Craig, 1997. The absence of W. zenobiae may well be a problem of collection as the specimens are flat and quite small. The Wilson Bluff Limestone is significantly richer in species and therefore more representative of the Wilson Bluff deposit than that of the Abrakurrie, in contrast to Li et al. (1996). All species found in the Abrakurrie Limestone are found in the Wilson Bluff Limestone, but it is less species rich, having only 8 species recorded from the deposit. This may be a result of lower water temperatures during the Late Oligocene to Early Miocene or a result of erosional effects that produced a sequence of hardgrounds (Li et al., 1996).

The brachiopods Murravia triangularis (Tate, 1880), Victorithyris garibaldiana (Davidson, 1862), and Terebratulina christopheri sp. nov. (Tate, 1880) are common to all five deposits, while T. christopheri insolta (Tate, 1880) are common to all five deposits, and W. zenobiae do not occur in the Abrakurrie Limestone but only one, W. zenobiae, different to the Wilson Bluff Limestone. This would suggest that the Toolinna Limestone has greater affinities to the Wilson Bluff deposit than that of the Abrakurrie, in contrast to Li et al. (1996). All species found in the Abrakurrie Limestone are found in the Wilson Bluff Limestone, but it is less species rich, having only 8 species recorded from the deposit. This may be a result of lower water temperatures during the Late Oligocene to Early Miocene or a result of erosional effects that produced a sequence of hardgrounds (Li et al., 1996).

The brachiopods Murravia triangularis (Tate, 1880), Victorithyris garibaldiana (Davidson, 1862), and Terebratulina christopheri sp. nov. (Tate, 1880) are common to all five deposits, while T. christopheri insolta (Tate, 1880) are common to all five deposits, and W. zenobiae do not occur in the Abrakurrie Limestone but only one, W. zenobiae, different to the Wilson Bluff Limestone. This would suggest that the Toolinna Limestone has greater affinities to the Wilson Bluff deposit than that of the Abrakurrie, in contrast to Li et al. (1996). All species found in the Abrakurrie Limestone are found in the Wilson Bluff Limestone, but it is less species rich, having only 8 species recorded from the deposit. This may be a result of lower water temperatures during the Late Oligocene to Early Miocene or a result of erosional effects that produced a sequence of hardgrounds (Li et al., 1996).

The brachiopods Murravia triangularis (Tate, 1880), Victorithyris garibaldiana (Davidson, 1862), Terebratulina christopheri sp. nov. (Tate, 1880), and Westralicrania zenobiae Craig, 1997 are not known from the Bremer and Eucla Basins of Western Australia have also been described from Late Eocene to Early Miocene deposits in south-eastern Australia (Table 19).

Specimens very similar to Lithothyrella labiata were described in Richardson (1971) and are recorded from the Tortachilla Limestone, Maslin Bay, South Australia. Westralicrania zenobiae Craig, 1997 is not known from south-eastern Australia.

Table 18 Brachiopod distribution over the deposits in the Bremer and Eucla Basins. (X indicates the presence of the species in the deposit) NL = Nanarup Limestone, PS = Pallinup Siltstone, WBL = Wilson Bluff Limestone, TL = Toolinna Limestone and AL = Abrakurrie Limestone.

<table>
<thead>
<tr>
<th>Species</th>
<th>NL</th>
<th>PS</th>
<th>WBL</th>
<th>TL</th>
<th>AL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldingia furculifera (Tate, 1880)</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Aliquantula insolita (Tate, 1880)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Anakinetic breva Richardson, 1991</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Austrothyris grandis (Tenison-Woods, 1865)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diedrothyris johnstoniana (Tate, 1880)</td>
<td>X</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Diedrothyris plicata Richardson, 1980</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Lithothyrella bulbosa (Tate, 1880)</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithothyrella subcarnea (Tate, 1880)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Magadinella woodsiana (Tate, 1880)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murravia triangularis (Tate, 1880)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stethothyris pectoralis (Tate, 1880)</td>
<td>X</td>
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<td>Stethothyris sufflata (Tate, 1880)</td>
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<td>X</td>
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</tr>
<tr>
<td>Stethothyris tapirina (Hutton, 1873)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Terebratulina christopheri sp. nov.</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Victorithyris divaricata (Tate, 1880)</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Victorithyris garibaldiana (Davidson, 1862)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Victorithyris tateana (Tate, 1880)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Westralicrania zenobiae Craig, 1997</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Table 19  Distribution of Bremer and Eucla Basin species in Australia, New Zealand and Antarctic. Ages identified in bold italics are for the appearance of the genus in these states.

<table>
<thead>
<tr>
<th>Species</th>
<th>WA: Age &amp; Fm</th>
<th>SA: Age</th>
<th>Vic: Age</th>
<th>Tas: Age</th>
<th>NZ: Age</th>
<th>Antarctica</th>
</tr>
</thead>
</table>
The genus *Neothyris* is not known from elsewhere in Australia and may be the result of separate evolution from Neothyridinae stock or the result of east to west movement of currents during a hiatus in the Proto-Leeuwin Current (Craig, 1999).

*Stethothyris tapirina* (Hutton, 1873) has not been recorded from elsewhere in Australia but is known from Oligocene deposits in New Zealand. It is likely that this species may be present in south-eastern Australian Late Eocene or Early Oligocene deposits.

The presence of so many species common to Western Australia and the south eastern states of Australia indicates that the abiotic ecological conditions were certainly similar for a long period from the Late Eocene to at least the Early Miocene. The presence of similar species in Western and South Australia during the Late Eocene agrees from Oligocene deposits in New Zealand. It is likely that this species may be present in South Australia during the Late Eocene agrees with the series of transgressions that extended from the Bremer Basin in Western Australia, across the Eucla Basin to the St Vincent Basin in South Australia. Richardson (1997) suggested that brachiopods are more influenced by substrate than by any other environmental condition. The fact that the brachiopod faunas are of greatest diversity in the bryozoan limestone formations of the Bremer and Eucla Basins tends to support this hypothesis.

Bryozoan limestone is the product of cool-water deposits possibly including up-welling (James personal communication). Although the surface temperatures due to the flow of the Proto-Leeuwin Current are said to be warm ranging from 17° to 19°, James and Bone (1991) suggested that water temperatures between 14° to 19° are cool enough to allow the deposition of bryozoan limestone. This does not preclude cool-water up-welling although Li and McGowran (1994) suggested that during cool water up-welling bryozoans are reduced in diversity.

Brachiopods and bryozoans are both lophophorates and sessile benthic filter feeders. It is likely that they occur in close association due to the availability of food or reduced light intensity, rather than for substrate conditions. Bryozoans are found on a variety of substrates, as are brachiopods.

The occurrence of similar species in the Murray Basin and the Torquay Basin during the Late Oligocene and Early Miocene to those in the southwest basins suggests that the species dispersed east and appeared in these areas once transgressions inundated the Tasman Rise. The mechanism for this distribution would most likely be the Proto-Leeuwin Current that is believed to have influenced the distribution of echinoids (McNamara, 1999) and large warm water foraminifers (McGowran et al., 1997). The influence of the Proto-Leeuwin Current on the distribution of brachiopods is also supported by the migration of Late Paleocene to Late Eocene brachiopods from the Carnarvon Basin to southern Australia (Craig, 2000). The present Leeuwin Current is defined as "a stream of warm, low salinity water that flows at the surface from near North West Cape to Cape Leeuwin and thence towards the Great Australian Bight (Cresswell, 1991: 1). There is strong circumstantial evidence for a direct, relatively short-term process of transportation of larvae of extant species of invertebrate and finfish from Western Australian spawning areas to South Australia nursery areas (Lenanton et al., 1991: 105).

The Cenozoic brachiopod fauna of New Zealand may have evolved from species, which first evolved in Western Australia. MacKinnon (1987) suggested that *Stethothyris* evolved from *Neothyris* esdailei Thomson, 1918. He also sees a close relationship between *Neothyris* esdailei Thomson, 1918 and *Victorithyris latana* (Tate, 1880), except for the loop, which in *Neothyris* esdailei Thomson, 1918 is trabecular while *Victorithyris latana* (Tate, 1880) is teloform. The genus *Victorithyris* has been recorded from the Late Paleocene Cardabia Formation, Carnarvon Basin, Western Australia (Craig, 2000). Three species of *Victorithyris* are described, the oldest from the Boongerooda Greensand. They differ from *V. latana* in the lack of plication. Hiller and MacKinnon (in press) suggest that a possible candidate for the ancestral form of *Victorithyris* could be from the Paleocene of Western Australia. Hiller and MacKinnon (in press) suggest that *Neothyris* esdailei Thomson 1918 may best be assigned to *Diedrothyris* Diedro thyris cf johnstoniana from the Cardabia Formation, Carnarvon Basin, Western Australia (Craig, 2000) and *D. johnstoniana* from the Nanarup Limestone indicates that the genus *Stethothyris* is more likely to have evolved from a species of *Victorithyris* or *Diedrothyris* in Western Australia. It would then have been dispersed due to the presence of the Proto-Leeuwin Current south along the western coastline and, with the Great Australian Bight Current, eastwards along southern coastline of Western Australia (McGowran et al., 1997). The presence of *Stethothyris* in the Nanarup Limestone supports this hypothesis.

Although the Trans-Tasman migration of echinoids is well established throughout the late Cenozoic (Foster and Philip, 1978) and Beu and Kitman (1998) suggested that molluscs migrate from west to east to New Zealand, the mechanism for such a migration of brachiopods across the widening Tasman sea is uncertain. There was a shallow marine connection between the Great Australian Bight and the Tasman Sea by the Late Eocene (Kennett, 1978; Beu et al., 1997). MacKinnon (1987) proposed that the Tasman Sea formed in the Late Cretaceous and that by the mid to Late Oligocene as the gap between Australia and Antarctica widened, the circum Antarctic current became established. He also suggested that strong
bottom currents scoured the gap between Australia and New Zealand prior to and after the breaching of the Tasman Rise. This would have made transport across the Tasman Sea by the brachiopods difficult as they have a short larval life of several hours to a few days (Richardson, 1997). One mechanism may have been the attachment of larvae to sea weed or other drifting material such as pumice and wood. Wignall and Simms (1990) reported the finding of *Rhynchonella subvariabilis* attached to a piece of fossil driftwood from the lower Mutabilis Zone (Lower Kimmeridge Clay, Upper Jurassic) at Wyke Rigis, Weymouth, Dorset, United Kingdom. McKinney and Jackson (1989) suggested that the only answer for the widespread distribution of bryozoans with a short larval phase would be such methods of rafting. Allan (1937) suggested that the only answer for the widespread distribution of these (Terebratellinae and Stethothyridinae) subfamilies.

There is also a continuous link of genera between Australia, New Zealand (*Terebratulina, Neothyris* and *Stethothyris* in common) and Antarctica (*Liothyrella, Terebratulina, Neothyris* and possibly *Stethothyris* in common) (Table 19). Bitner (1996) described a species of *Stethothyris* from the Late Eocene La Meseta Formation of Seymour Island. If this identification is correct, then *Stethothyris* may have a wider range and different history than proposed by Hiller and MacKinnon (in press). The genera, which are in common between the three shelves, may have evolved along the Antarctic shelf. Movement to New Zealand might be then explained by drift north from Antarctica. Unfortunately, there are no fossil deposits including brachiopods from this region of Antarctica. Movement westwards from the Antarctic Peninsula could only have occurred after the opening of the seaway between South America and Antarctica in the Late Oligocene (Foster, 1974) and would have been against the recognised current flow patterns (Kennett, 1978). Further examination of south eastern Australian, Antarctic and South American specimens should provide the evidence required to settle the evolutionary history and biogeographical distribution of these (Terebratellinae and Stethothyridinae) subfamilies.

**ACKNOWLEDGEMENTS**

I would like to take this opportunity to thank Dr Noel James and Dr D. I. MacKinnon, for their input in the preparation of this paper. Ms Kris Brimmell prepared the photographs of *Westralicrania xenobiace*. I would also like to thank Dr K. J. McNamara for his review and comments, the Western Australian Museum for their support during my research and the Geological Society of Western Australia for the loan of the specimens collected by D. C. Lowry.

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Cenozoic Brachiopoda of the Bremer and Eucla Basins


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Richardson, J.R (1959). Cenozoic Terebratuloid and


*Manuscript received 2 August 1999; accepted 14 March 2000.*
A description of additional variation seen in the scale morphology of the Frasnian thelodont *Australolepis seddoni* Turner and Dring, 1981

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Department of Geology and Geophysics, The University of Western Australia, Nedlands, Western Australia 6907, Australia

Abstract - Isolated scales are referred to the thelodont *Australolepis seddoni* from the (Frasnian) Gneudna Formation, Carnarvon Basin, Western Australia. A total of 670 scales was examined in comparison to the original sample of 60 scales, and it is considered that the majority of these scales represent morphological variation within *A. seddoni*. The scales were then assigned to different body regions based on their morphology. In addition to *A. seddoni* scales, two other scale types were recognized and these were referred to the genus "*Skamolepis*." The presence of this genus in the Gneudna Formation suggests a close link between the faunas of Western Australia and central Iran.

INTRODUCTION

The first thelodont scales to be described from Frasnian aged sediments occur in the Gneudna Formation, Carnarvon Basin, Western Australia (Turner and Dring 1981). This occurrence extended the range of thelodonts to the Upper Devonian. However, to date Frasnian thelodonts are only recorded from Gondwanan strata (Turner 1997). The original description of *Australolepis seddoni* Turner and Dring, 1981, was based on a scale sample of about 60 specimens from the middle of the type section (KT beds 13-15), which were referred to head, trunk and transitional scales based on the system of Gross (1967) which was then in use. These scales were distinctive in having highly crenulated crowns, and navicular or horn-like ridges, often bifurcated at the perimeter of the crown.

Further sampling of the Gneudna Formation has yielded many more thelodont scales, allowing a greater understanding of the intraspecific variation within *A. seddoni*, and resulting in another six scale types (*sensu* Märs 1986) being described. Four of the additional scale variants are transitional scales and show a gradation into the "nikoliviid" scale type. Turner and Dring (1981) originally considered this tripartite crowned scale as a separate species, nikoliviid gen. et sp. indet. However, Turner (1993, 1997) considered these scales as variants of *A. seddoni*. After taking into consideration the increased variation in scale morphology within *A. seddoni*, scales previously referred to as *Turinia* sp. cf. *anarchica* from the Gneudna Formation, Western Australia (Long and Trinajstic in press) are now referred to *A. seddoni*. One other thelodont scale type, with a flattened and posteriorly flaring crown, has been found in the Gneudna Formation and this is described and referred to the genus "*Skamolepis*" Turner and Janvier, 1979.

Through the study of articulated specimens, considerable variation in the morphology of scales has been observed in many thelodont species (Gross 1967, 1968; Karatajute-Talimaa 1978; Märs 1986; Turner 1976). With reference to the new scale variants of *A. seddoni* described, the possible range of morphological variation within *A. seddoni* is discussed. Based on the morphological variation studied in several articulated thelodont genera, Märs (1986) described a pattern of squamation based on five distinct morphological areas, providing a uniform reference for the identification of isolated thelodont scales. The possible body regions from which the scales of *A. seddoni* originated are discussed in reference to the five regions defined by Märs (1986).

MATERIALS AND METHODS

The thelodont scales described are from the type section of the Gneudna Formation, Williamsbury Station, Western Australia (Figure 1). Scales described in this paper come from the residue of limestone samples digested in 10% acetic (Rixon 1979). A total of 670 scales was examined in comparison to the original sample of 60 scales. The scanning electron micrographs were made on a Philips 505 at the Centre for Microscopy and Microanalysis, The University of Western Australia. Thin sections of scales were made by handgrinding and examined under confocal and light microscopes. Specimens have been deposited in the collections of the Western Australian Museum (WAM).
Figure 1 Stratigraphic column indicating the beds in which thelodonts occur in the Gneudna Formation and a map of Western Australia showing the location of the Gneudna Formation.
Emended Diagnosis
A scale species with major crown ribs that often have an ornament of small tubercles. Scales are small to medium-sized, mostly 0.5–1 mm long. Those scales with lappets also have a pronounced, fine ribbed micro-ornament. Trunk scales are often characterised by multidigitate lappets. Scales show a typical turiniid histology.

Remarks
The scales described in this study represent variants of *A. seddoni* not formally described. They differ from previously described *A. seddoni* scales (Turner and Dring, 1981) in possessing a micro-ornament of fine parallel ribs, tubercles on the main ribs and upward projecting neck spurs. *A. seddoni* scales can be separated from the scales of *Turinia antarctica* Turner and Young, 1992 by the absence of minor rib tubercles, the absence of narrow troughs subdividing major crown ribs, and the generally greater complexity of the crown ribbing. *A. seddoni* scales can be separated from the scales of *Turinia pagoda* Wang et al., 1986 by the more delicate and deeply dissected crowns, and the less developed neck spurs found in *A. seddoni*. The absence of double ribs in *A. seddoni* scales separate them from scales of *Turinia gavinyoungi* Turner, 1995 and *Turinia hutkensis*.

Description of scale variants in *A. seddoni*

**Scale Type 1**

*Material*
20 scales WAM 99.8.15–18 (Figure 2A–B)

*Horizon*
KT beds 4, 12, 13, and 14 (Figure 1).

*Description*
The scale is sub-rounded in outline. There are eight ribs radiating from a high, rounded central apex to a narrow, shallow neck (Figure 2A). Wide troughs separate the ribs. The ribs all bifurcate at the interface with the crown neck. At the distal margin of each rib are six rounded tubercles (Figure 2B), similar to those seen in *T. antarctica* (Turner and Young, 1992, figure 4a–e). In addition to the tubercles, is a micro-ornament of fine, parallel ribs, which is present on the distal margin of each rib and along the apex of each rib (Figure 2B). Although *A. seddoni* type 1 scales are similar to *T. antarctica* scales, they are differentiated by the lower number of ribs, the lower number of rib tubercles and the absence of double ribbing. The base is slightly wider than the crown, and there is a low neck. There are no neck-spurs present, but there are twelve bean-like swellings around the basal pulp cavity, similar to the swellings seen in the type sample of *A. seddoni* and *T. pagoda* (Wang et al., 1986, figure 5A–B).

**Scale Type 2**

*Material*
10 scales WAM 99.8.19–21 (Figure 2C)

*Horizon*
KT beds 4, 12, and 14 (Figure 1).

*Description*
These broad scales are low in profile. The apex of the crown is positioned above the posterior third of the scale (Figure 2C). Two posteriorly bifurcating ribs dissect the anterior scale face. Along the apex of the bifurcated ribs are small tubercles, similar to those present in scale type 1. Two deep troughs separate the lateral lappets projecting from below the crown apex, from the anterior portion of the crown. Posteriorly, the apex terminates in three deep ribs. The posterior lateral lappets have a micro-ornament of fine, parallel ribs (Figure 2C). These scales appear similar to a transitional scale figured by Turner and Dring (1981, figure 4J). They can be distinguished from this scale type by the presence of tubercles on the anterior ribs, and by the micro-ornament present on the posterior lappets (Figure 2C).

The flat base is wider than the crown, and there is a wide pulp cavity. In this respect the base does not differ from previously described *A. seddoni* scales (Turner and Dring 1981).

**Scale Type 3**

*Material*
20 scales WAM 99.8.22–25 (Figure 2D)

*Horizon*
KT beds 4, 12, 13 and 14 (Figure 1).
Description
The crown of scale type 3 is tripartite (Figure 2D). The anterior face of the crown has two prominent ribs which bifurcate close to the interface of the crown with the neck. The central section of the crown is triangular and there is a wide plateau extending to form two lateral lappets. The lappets branch at the distal margins. The third division of the crown consists of a single, median rib with two bulbous projections off each side. The elliptical base is wider than the crown, and does not possess an anterior spur. There is a large pulp cavity in the base of the scale.

Scale Type 4
Material
18 scales WAM 99.8.26–30 (Figure 2E)

Horizon
KT beds 4, 12, 13, 14 and 15 (Figure 1).

Description
These scales are high crowned with acute apices (Figure 2E). The anterior face has one prominent rib that branches approximately halfway along to form three ribs. On the posterior margin of the crown are two elongate spurs, projecting upwards. The location and shape of the neck spurs are similar to those on the body scales of *Turinia pagoda* (Wang et al., 1986, figure 4a–f). However, there are far fewer neck spurs on *A. seddonii* scales. There is a shallow, narrow neck. The base of the scale is narrower than the crown and there is no anterior process. There are six bean-like projections around the basal pulp canal similar to those found in *T. pagoda* (Wang et al., 1986).

Scale Type 5
Material
20 scales WAM 99.8.31–34 (Figure 2F)

Horizon
KT beds 4, 12, 13 and 14 (Figure 1).

Description
This medium sized, navicular scale has four ridges on the anterior face of the crown which converge, and taper posteriorly towards a high apex (Figure 2F). There is an ornament of small tubercles along the distal third of the ribs, near the crown-neck interface. The posterior region of the scale is divided into three sections by narrow ridges which terminate in three small, upturned neck-spurs, similar to those in *T. pagoda* (Wang et al., 1986). The neck is a smooth, narrow furrow, and the base is slightly larger than the crown. There is a small anterior process on the base (Figure 2F). There are six small, bead like swellings around the basal pulp cavity. This scale type, in the presence of upturned neck-spurs and bead like swellings around the basal pulp cavity, resembles trunk scales of *Turinia pagoda* (Wang et al., 1986, figure 6 A). The scale is distinguished from *T. pagoda* by the high crown apex, lesser development of the neck-spurs and the absence of micro-ornament.

Scale Type 6
Material
15 scales WAM 99.8.35–37

Horizon
KT beds 4, 12 and 14 (Figure 1).

Description
In scale type 6, the anterior face of the crown has a well-defined, bifurcated rib. This extends from the margin of the scale, and terminates almost at the crown apex. The scale is separated into three sections by highly developed, ridged lateral lappets. Both sets of lappets curve posteriorly. The base is wide, with a small anterior process, and the neck is shallow. The lack of micro-ornament distinguishes this scale from superficially similar *Turinia antarctica* scales (Turner and Young, 1992).

Scale Type 7
Material
12 scales WAM 99.8.38–41 (Figure 2G)

Horizon
KT beds 4, 12, 13 and 14 (Figure 1).

Description
In this scale type the crown is divided into three sections. The anterior face of the crown has two prominent ribs which bifurcate approximately halfway down each rib. The ribs have a slightly scalloped appearance. The middle section of the crown also has two ribs and these extend outward, with two wide lateral lappets forming off the distal end of each rib. The lappets branch at the lateral margins, with each branch terminating in a rounded tubercle. There is a micro-ornament of parallel ribs on the most distal portion of the lappets. The third division of the crown consists of a single median rib with two narrow lappets projecting off each side. The elliptical base is wider than the crown and does not possess an anterior spur. There is a large pulp cavity in the base of the scale.

Scale Type 8
Material
17 scales WAM 99.8.42–45 (Figure 2H & I)
Scale morphology in *Australolepis seddoni*

**Figure 2** Scales designated as *Australolepis seddoni*. A-B morphotype 1 - oral scales, C morphotype 2 - cephalopectoral scales, D morphotype 3 - post-pectoral scales, E morphotype 4 - precaudal scales, F morphotype 5 - precaudal scales, G morphotype 7 - precaudal scales, H-L morphotype 8 - precaudal scales, J morphotype 9 - fin scales, K morphotype 10 - fin scales, L Thin section of morphotype 1 scale photographed under a confocal microscope. Scale Bars A, C–H, J–L = 1.0 mm, B, I = 0.1 mm.

**Horizon**

KT beds 4, 12, 14 and 22 (Figure 1).

**Description**

The crown of scale type 8 is almost identical to scale type 7. The primary difference occurs in the central section of the crown. Here the ribs continue to the base, the lappendes forming behind the main ribs. Each lappen projects posteriorly and is dissected by a single strong rib. The microornament is more developed in this scale compared to the scales previously described (Figure 2L). Fine parallel ribs are present on the lappets, the anterior edges of the middle section of the crown, and on the posterior section of the crown where they continue half way down the crown face. In this respect these scales are more similar to the scales of *T. antarctica* (Turner and Young 1992). The base differs considerably from the other scales described, being laterally and anteriorly expanded. There is a well developed anterior process on the central anterior margin. A
well developed anterior spur is seen in other Gondwanan thelodonts including *T. pagoda*, *T. antarctica*, *T. hutkensis*, *T. gondwana* Turner, 1989 and *T. australiensis* Gross, 1971.

**Scale Type 9**

**Material**
20 scales WAM 99.8.46–49 (Figure 2J)

**Horizon**
KT beds 4, 12, 13 and 14 (Figure 1).

**Description**
This scale type has a similar form to the above tripartite scales. However, it is narrower, and the lateral lappets are not as developed. There is a deeply bifurcated single rib on the anterior face. The bifurcation occurs almost at the apex of the rib. The central portion of the scale is formed by two lateral ribs which terminate in one upturned projection. The posterior section of the scale is formed from two ribs again forming from the scale apex. The ribs expand posteriorly and terminate in upturned projections. There is a small amount of micro-ornament on the posterior lappets. The base is wide and anteriorly expanded. There is a small, rounded anterior process. There are several bead like projections towards the posterior margins of the base.

**Scale Type 10**

**Material**
20 scales WAM 99.8.50–53 (Figure 2K)

**Horizon**
KT beds 4, 12, 13 and 14.

**Description**
This scale is similar to the scale described above having the crown divided into three partitions. On the anterior crown face there are two ribs which are positioned close together and do not bifurcate. The middle section of the crown, like scale type 9, consists of two outwardly projecting ribs which form wide lappets on the distal margin of each rib. These lappets project posteriorly and are crenulated. There is a fine micro-ornament of parallel ribs around the anterior margin of the lappets. The posterior section of the crown consists of a single medium rib which widens posteriorly to form two lateral lappets. The lappets terminate in high acute points with a micro-ornament around the anterior edges. The base of the scale is rounded and is expanded anteriorly. There is a rounded anterior process which is more developed than the anterior process in scale type 9.

**Scale Type 11**

**Material**
10 scales WAM 99.8.54–55 (Figure 3A–D)

**Horizon**
KT beds 13 and 14 (Figure 1).

**Description**
Scales belonging to scale type 11 have a tripartite crown. There is a single, major rib on the anterior crown face which divides in two, at the midline. There are numerous small rib tubercles along the length of the main rib. The tiered complexity of the crown in scale type 11 is similar to the crown complexity present in *T. gondwana* recorded from Bolivia (Gagnier et al., 1989) and *T. gavinyoungi* (Turner, 1995) recorded from Australia. The crown expands outwards and backwards. There are two sets of well developed lateral, multiddigitated lappets that extend well over the base. There is a micro-ornament of fine parallel ribs on the lappets, and on the main body of the scale (Figure 3D). The base is wider than the crown and there is a long anterior process.

**Histology** (Figure 2L)
All these scales exhibit typical thelodontid histology (sensu Gross, 1967) as described in the type specimens described by Turner and Dring (1981). There is a crown of orthodentine and a base of aspidin-like tissue. In thin section fine dentine tubules can be identified radiating from the pulp canal.

**Remarks**
The increased sample size has yielded eleven new variations of *Australolepis seddoni* scale types. The new morphological features present in these additional scales indicate a closer relationship between *A. seddoni* and the other Gondwanan thelodonts, *T. antarctica*, *T. gavinyoungi*, *T. hutkensis* and *T. pagoda*. The scales of *A. seddoni* with highly developed lappets are very similar in form to *T. antarctica*, *T. gavinyoungi*, *T. gondwana* and *T. pagoda*. These scales share tripartite subdivision of the crown and multiddigitated lappets. There is also considerable similarity noted between *A. seddoni* and *T. gondwana*, as these species also share a tripartite crown, bifurcated ribbing and a large elongated pulp canal opening.

The presence of neck-spurs in two of the new scale type variations increases the number of characters shared between *A. seddoni* and *T. pagoda*. Wang et al. (1986) stated a major difference between *T. pagoda* and *A. seddoni* was the absence of neck-spurs however, they did note the resemblance in the basal structure and general crown form of the scales. It is possible to unite *T. pagoda* and *A. seddoni* in the genus...
**Australolepis** on the basis of the shared characters: lateral lappets and bead like projections on the base and neck-spurs. However, as the description of *T. pagoda* is based on only six scales it would seem premature to unite these taxa until the full range of variation of *T. pagoda* is known. It is conceivable that all these species represent members of a single Gondwanan genus *Australolepis* (S. Turner and T. Märss, personal communication 1996). A revision of the genus may be required as the Middle and Upper Devonian turiniids of Australia share more in common with those in Antarctica, West Yunnan, Iran, and Bolivia than with turiniids from the Northern Hemisphere (Turner, 1997).

Allocation of Scale Varieties from *A. seddoni* to Body Regions.

Märss (1986) established that the scale varieties on the articulated specimens of *Phlebolepis* could be distinguished on other thelodonts. Five separate regions with distinct scale morphologies were recognised to occur on individual thelodonts. These were the oral, cephalo-pectoral, postpectoral, precaudal and pinnal regions (Märss, 1986, figure 3).
7). On Phlebolepis elegens Pander, 1856, 28 different scale types were determined and on P. ornala Marss, 1986 22 different scale types were recognized. With the additional scales described here for A. seddoni a total of 28 scale types are now recognised, so it is probable that all these variants did in fact come from the one species.

Scales of type 1 (Figure 2A-B, Figure 4) are considered to represent oral scales (equivalent to head scales of Gross (1967) and Turner and Dring (1981)). Marss (1986) characterises oral scales as having rhombic to rounded crowns with marginal notches and ridges that are orientated toward the crown centre. Cephalo-pectoral scales (transitional scales; Gross (1967) and Turner and Dring (1981)) are large, oval to rhombic scales with short ribs and are generally unsculptured (Marss, 1986). Scales attributed as type 2 (Figure 2C, Figure 4) correspond to this variety. The scales Turner and Dring (1981, figure 6a-c) attributed to nickoliviid type are also considered to represent cephalo-pectoral scales (Figure 4). Post-pectoral scales are represented by scale type 3 (Figure 2D, Figure 4). These scales also lack ornament. The majority of the new scale types described (scale types 4-8) are represented by precaudal scales (Figure 2 E-I, Figure 4). Precaudal scales are characterised by having a wedge shape, a sculptured pattern and a reduced number of lateral ridges (Marss 1986). These scales also commonly have an anterior spur.

Scale Type 12

Material
5 scales WAM 99.8.56-57 (Figure 3E)

Horizon
KT beds 4 & 12 (Figure 1).

Description
These scales have an unusual shape when compared to other thelodont scales. The crown is slender and flares posteriorly beyond the base. There is an ornamented of parallel single ribs with small tubercles on the rib surfaces. On the lateral margins of the crown are two dorsal side lappets, each with a fine micro-ornament of narrow ribs. There is a constricted neck on a low round base. The base is as wide as the crown. There is an anterior process. There is a large pulp cavity that widens anteriorly.

Scale Type 13

Material
15 scales WAM 99.8.58-60 (Figure 3F-G)

Horizon
KT beds 4, 12 and 14 (Figure 1).

Description
These scales are similar to scale type 1. It differs in the base being wider and the posterior crown being not as flared, instead terminating in seven rounded projections. The crown is long, projecting over the base posteriorly. It has an ornament of four lateral parallel ribs and a central rib that bifurcates at approximately half the crown height. The neck is very low and there is a central anterior process. On the ventral surface there is a large pulp opening.

Remarks
Scales originally referred to Skamolepis fragilis Karatajute-Talimaa, 1978 from the late Emsian to early Eifelian of Europe are now considered to be shark denticles by Turner (1991, 1993). Karatajute-Talimaa (1978) still thinks that the genus Skamolepis belong to thelodont scales. Shark denticles which resemble the Baltic scales are still under review. Turner (personal communication 1998) suggests that a new genus may be required for those. However, more material is needed before this can occur.

The scales from the Gneudna Formation closely resemble scales B and C referred to as "Skamolepis" (Turner and Janvier, 1979, figure 1, B1-3, C1-3) from the Khush-Yeilagh Formation in Iran (Turner and Janvier, 1979). Scale type 12 also shows some resemblance to a scale referred to Thelodons trilobatus from Irian Jaya (Turner et al., 1995). The Gneudna scale however, is higher in profile, the central ridge narrows dorsally (the opposite condition is seen in T. trilobatus), and the base extends beyond the lateral and anterior margins of the crown.

DISCUSSION

The range and distribution of thelodonts in Australia has been clarified over the last ten years (Turner 1995, 1997; Young 1995). Since the discovery of Frasnian thelodonts in the Carnarvon Basin, A. seddoni has been recorded in Australia from the Virgin Hills Formation, east of Fitzroy Crossing in the Canning Basin and from the Givetian Papilio Formation, Broken River in North Queensland (Turner, 1997).
undescribed, thelodont remains have been found in the Lawford Ranges (Turner and Young, 1992; Turner, 1997). Some of these scales have been compared to Turinia antarctica Turner and Young, 1992 but Turner (1994, 1997) referred others to A. seddoni. With the discovery of greater variation in the scales of A. seddoni it is probable that these scales can be now verified as belonging to A. seddoni. Outside Australia Australolepis was tentatively reported from the Holy Cross Mountains fauna in Poland (Ginter, in Turner, 1995). However, it is now thought that these scales may in fact be chondrichthyan (Turner, 1997). Scales of A. seddoni occur in the early Frasnian deposits at Kale-Sader in the basal Shishtu Formation in eastern Iran (Turner, 1997; Yazdi et al., 1998). The discovery of a second thelodont in the Gneudna Formation also supports the closeness of the Frasnian faunas from eastern and central Iran to those in Western Australia.

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Cover: The Bilby, Macrotis lagotis.
Illustration by Jill Ruse.
Biodiversity of shallow reef fish assemblages in Western Australia using a rapid censusing technique

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Abstract - A rapid assessment methodology was used to provide relative abundance data on selected families of Western Australian fishes. Twenty shallow water reef sites were surveyed covering the coastline between the Recherche Archipelago in the south east and the Kimberley in the north. Three groups of atolls located off the Kimberley coast were also included. Eighteen families that best represent the State's nearshore reef fish fauna were targeted. They are: Serranidae, Caesionidae, Lutjanidae, Haemulidae, Lethrinidae, Mullidae, Pempherididae, Kyphosidae, Girellidae, Scorpididae, Chaetodontidae, Pomacanthidae, Pomacentridae, Cheilodactylidae, Labridae, Odacidae, Acanthuridae, and Monacanthidae. Analysis of the dataset using a hierarchical classification technique indicates that four groups of reef fishes are present: a southwest assemblage, a northwest assemblage, an offshore atolls assemblage, and a Kimberley assemblage. The first assemblage is comprised mainly of temperate species, while the latter three are mostly tropical fishes; these two broader groupings narrowly overlap on the west coast between Kalbarri and the Houtman Abrolhos. Evidence of a wide zone of temperate/tropical overlap—as proposed by some previous studies—is not supported by this analysis, nor is the presence of a prominent subtropical fauna on the west coast. Ecological differences of the four assemblages are explored, as well as the impact by the Leeuwin Current on this arrangement.

INTRODUCTION
Western Australia occupies about 23 degrees of latitude (12–35°S) covering a large and varied aquatic ecosystem. Its fish fauna, at just over 3000 species, is recognised as possibly the most diverse in Australia (Hutchins, 2001). About 1500 of these are associated with shallow reefs (0–40 m), and make up the majority of fishes that best identify the Western Australian fauna. They range from diverse coral-dwelling fishes of the northern atolls to the cool water inhabitants of the State's southern rocky reefs. However, human impact on these fishes is increasing; reef fishes represent the core of recreational catches and their often gaudy colouration attracts the attention of swimmers and divers. Many are targeted by professional fishermen which has led to a reduction in numbers of some of the more popular species (e.g., coral trout). Because of this notoriety, demand for information on their biodiversity has accelerated over the last two decades. Although contemporary studies of reef fish diversity have focussed attention on various regions of the State (e.g., Hutchins, 1990; Allen, 1993b), few have been able to examine large-scale spatial changes in the fauna. One recent study (Hutchins, 1994) looked at distributions along the western and southern coasts of the State, but could only provide a brief comparison with other more northern areas. The main stumbling block was the lack of reliable data from the more isolated parts of the Pilbara and Kimberley coasts. Subsequent investigations (e.g., Hutchins, 1995a, 1996b), however, have helped to overcome this deficiency. For the first time, an analysis of reef fish assemblages across the various marine regions of Western Australia is possible. The coverage is broad enough to allow a close examination of their biodiversity, although much of the present dataset is based on exploratory work and future efforts will doubtlessly lead to some changes in its interpretation.

Reef fish assemblages of shallow waters lend themselves to study because of their relatively easily accessible habitat, their familiarity to researchers, and the increasing comprehensiveness of taxonomic knowledge. In particular, many reef fish families are comprised of species that spend much of their time in the open and are generally easy for divers to record visually. Lately, surveys employing visual techniques have gained wider acceptance for estimating species diversity than the previous specimen collecting methodology.
Figure 1  Map of Western Australia showing many of the localities mentioned in the text. Insert depicts the location and approximate range of each of the 20 survey sites as described in the Methods section.
Rapid censusing technique for reef fish

(Anonymous, 1978). Nevertheless, a combination of the two is still necessary when preparing lists of biodiversity. Many cryptic species remain hidden in the reef structure and must be forcibly removed using a variety of collecting procedures. For analysis, however, the rapid assessment technique (Williams, 1982) incorporating visual surveys that target particular families has many benefits. This semiquantitative method can allow reasonably accurate comparisons to be made between various study sites (e.g., Newman et al., 1997); it is also non-destructive, and involves less time and resources that more comprehensive investigations demand.

The present paper deals with the results of a series of surveys carried out at 20 major locations in Western Australia (Figure 1) by the author and colleagues from various institutions (seeAcknowledgements for a list of participants). The surveys commenced in 1978 and have continued to the present. The data presented here were gathered using the rapid assessment methodology mentioned above and described more fully in the methods section below. Eighteen families were targeted (Table 1), six of which consist wholly of tropical species, four almost entirely of temperate species (two subtropical species are included) and eight with a mixture of tropical, subtropical and temperate species. Almost 500 species of shallow reef fishes are represented by these families in Western Australia, including many of the species that attract the attention of divers and are recognised as typical reef inhabitants. Apparent spatial variations of these taxa are easier to detect than changes to other less visible species, and therefore should be more representative of changes within the fish fauna as a whole. The dataset is presented in several ways, including a complete listing of species, data summaries in tabular form, and a hierarchical classification that indicates the degree of similarity of the various fish assemblages. The resulting spatial pattern is examined in the context of previous studies.

METHODS

The method of survey was based initially on the visual survey technique described in Wilson and Marsh (1979) but subsequently modified after Williams (1982). Fish were counted during a 45–60 minute swim in which the observer swam in a zigzag course around each survey location. Records were noted on underwater sheets that had previously been filled out with the names of species most likely to be found, and scored in a log scale of abundance (1 = 1 fish; 2 = 2–5; 3 = 6–25; 4 = 26–125; 5 = 126–625; 6 = 626–3125; 7 = 3126+). All identifiable species were recorded but particular emphasis was placed on the target families. Species not normally associated with shallow reefs (e.g., rare sightings of deepwater dwellers) are not covered here. However, seagrass and sandy bottom inhabitants that often enter the reef system are included. Most survey activity occurred in the depth range 0–20 m, but depths to 30 m were occasionally worked. The reader is also referred to Anonymous (1978) and Halford and Thompson (1994) for additional information on reef fish censusing.

The terminology used here follows Hutchins (1994). Biodiversity is usually defined as the number of species present (Helfman et al., 1997), but is also employed here to infer geographic changes in diversity. Species referred to as endemic are those with breeding ranges restricted to Western Australia. The phylogenetic order and arrangement of the families follow Paxton et al. (1989). Much of the survey work has previously been reported in published and unpublished reports, all of which are listed in the bibliography at the rear of this paper (see Allen, 1977, 1992, 1993a-b, 1996; Allen and Russell, 1986; Allen and Swainston, 1988; Hutchins, 1977, 1978, 1979, 1990, 1994, 1995a-b, 1996a-b, 1997b-c, 1998, 1999; Hutchins and Swainston, 1986; Hutchins and Thompson, 1983; Hutchins et al., 1995; and Morrison and Hutchins, 1997). In addition, a full list of species known for Western Australia with a comprehensive bibliography can be found in Hutchins (in press).

Sites

The sites selected for analysis are shown in Figure 1, and are briefly described below (grouped into seven approximate geographical regions). Additional information on sites along the west and south coasts can be found in Hutchins (1994).

South coast

Site 1 – Recherche Archipelago, from Israelite Bay to Esperance. Twilight Cove, which is located further to the east and was examined by Hutchins (1994), is not included in the present analysis due to the limited nature of its dataset.

Site 2 – Albany area, from Cheyne Beach to Walpole.

Site 3 – Capes area, from Cape Leeuwin to Cape Naturaliste, including Geographe Bay.

Lower west coast

Site 4 – Perth area, from Rockingham to Lancelin. Rottnest Island, which was treated as a separate site by Hutchins (1994), is included here.

Site 5 – Port Denison area, from Jurien Bay to Port Denison.

Central west coast

Site 6 – Houtman Abrolhos, including all offshore islands in the region.
Site 7 – Kalbarri area, from Port Gregory to Kalbarri.

**Upper west coast**
Site 8 – Shark Bay (western portion), from South Passage to Bernier Island.
Site 9 – Coral Bay area, from Point Quobba to Coral Bay.

**Northwest coast**
Site 10 – Ningaloo Reef, from Ningaloo to North West Cape.
Site 11 – West Pilbara islands, from Muiron Islands to Boodie Island, but not including Barrow Island or the Lowendahl Islands (data not available) (Hutchins [1994] included the offshore Muiron Islands with Ningaloo Reef).
Site 12 – Monte Bello Islands.
Site 13 – Dampier Archipelago, from Kendrew Island to Delambre Island, and including northern parts of the Burrup Peninsula.

**Offshore atolls**
Site 14 – Rowley Shoals (Imperieuse, Clerke, and Mermaid Reefs)
Site 15 – Scott and Seringapatam Reefs
Site 16 – Ashmore Reef and Cartier Island

**Kimberley**
Site 17 – Southwest Kimberley, from Broome to Cape Leveque, but not including the offshore Lacepede Islands (data not available).
Site 18 – North Kimberley (inshore), from the Buccaneer Archipelago to Montgomery Reef.
Site 19 – North Kimberley (offshore), from Churchill Reef, through the Bonaparte Archipelago to Cassini Island.
Site 20 – Northeast Kimberley, from Vansittart Bay to Cambridge Gulf.

**Analysis**
Sites were classified into groups by a hierarchical classification analysis employing the computer program NTSYSPC 2.0. Bray-Curtis similarity coefficients were used, and matrices clustered using the UPGMA clustering method. Log_{abundances were determined for all species recorded during each individual survey swim, the means calculated for each site and then rounded to the nearest whole number, usually between 1 and 4 (a few mean values at sites 14, 15 and 16 were calculated as 5 but were still entered as 4). This simplistic approach was adopted for several reasons: 1. The survey effort was higher in some areas than others, and therefore is not directly comparable; 2. The times spent censusing fish were not standardised until the early 1990’s; and 3. No single calculation can be expected to accurately describe abundance over the wide range of reef habitat that exists at each of the 20 survey sites. Therefore, the abundance data presented in Appendix 1 could be best described as broad estimates for each site that equate to the following: blank = not recorded; 1 = rare; 2 = occasional; 3 =

### Table 1 Numbers of species per family recorded from 20 sites in Western Australia

<table>
<thead>
<tr>
<th>Regions</th>
<th>South Coast</th>
<th>Lower W Coast</th>
<th>Central W Coast</th>
<th>Upper W Coast</th>
<th>NW Coast</th>
<th>Atolls</th>
<th>Kimberley</th>
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<td>14 15 16</td>
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<td>11 12</td>
<td>13 14 15 16</td>
<td>17 18 19</td>
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<tr>
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<td>16 17 18</td>
<td>18</td>
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</tr>
<tr>
<td>Monacanthidae</td>
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<td>16 17</td>
<td>18 19 20 21</td>
<td>22 23 24</td>
<td>24</td>
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</tbody>
</table>

Total sites: 54 56 64 112 83 152 62 178 171 230 234 174 186 228 271 290 69 62 121 46

Total: 68 118 156 203 267 344 414 493
Table 2 Numbers of tropical, subtropical and temperate fishes per family recorded from 20 sites in Western Australia

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<tr>
<th>Tropical</th>
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<th>Temperate</th>
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<td>Haemulidae</td>
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<tr>
<td>Lethrinidae</td>
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<tr>
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<tr>
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<td>1</td>
</tr>
<tr>
<td>Girellidae</td>
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<td>2</td>
</tr>
<tr>
<td>Scorpididae</td>
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<tr>
<td>Chaetodontidae</td>
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<td>1</td>
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<tr>
<td>Pomacanthidae</td>
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<td>Labridae</td>
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<tr>
<td>Monacanthidae</td>
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</tr>
</tbody>
</table>

Total 427 17 49

frequent; 4 = abundant. For comparative purposes, a second analysis of this dataset was performed using a presence-absence format only.

Results

A total of 493 species of reef-associated fishes were recorded for the 18 families examined during this investigation. These are listed by family in Appendix 1, together with estimates of their relative abundance at each of the twenty survey sites. Also, the latitudinal range of each species is indicated by one of three biogeographical descriptors (i.e., tropical, subtropical, or temperate), and species endemic to Western Australia are denoted by an asterisk. The following summaries of the dataset are presented in tabular form: species numbers per family (Table 1); species numbers per biogeographical category (Tables 2 and 3); numbers of endemic species per biogeographical category (Table 4), most abundant species at three or more sites (Table 5); and species numbers shared between the seven geographical regions (Table 6).

Regionally, the greatest number of taxa were recorded at the offshore atolls (344 species), the numbers decreasing southwards to the south coast (68 species) (Table 1). However, the Kimberley’s unexpectedly low figure of 141 species places it between the central west coast (156 species) and the lower west coast (118). Ashmore Reef (290 species) had the highest species richness of the survey sites, followed by Scott/Seringapatam (271 species), West Pilbara islands (234), Ningaloo Reef (230), Rowley Shoals (228), Dampier Archipelago (186), Shark Bay (178), Monte Bello Islands (174), Coral Bay (171), and Houtman Abrolhos (152). All of these locations had predominantly tropical faunas, although two—

Table 3 Numbers of tropical, subtropical and temperate fishes recorded from 20 sites in Western Australia.

<table>
<thead>
<tr>
<th>Sites</th>
<th>South coast</th>
<th>Lower W coast</th>
<th>Central W coast</th>
<th>Upper W coast</th>
<th>NW coast</th>
<th>Atolls</th>
<th>Kimberley</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical</td>
<td>1 4</td>
<td>48 27</td>
<td>112</td>
<td>35 155</td>
<td>159 221</td>
<td>174 288</td>
<td>186 228</td>
</tr>
<tr>
<td>Subtropical</td>
<td>7 13</td>
<td>17 17</td>
<td>17</td>
<td>5</td>
<td>5</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Temperate</td>
<td>47 47</td>
<td>47 39</td>
<td>23</td>
<td>12</td>
<td>230</td>
<td>234</td>
<td>174 186</td>
</tr>
<tr>
<td>Total Endemics</td>
<td>54</td>
<td>56</td>
<td>64</td>
<td>112</td>
<td>83</td>
<td>152</td>
<td>62</td>
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</table>

Table 4 Numbers of endemic tropical, subtropical and temperate fishes recorded from 20 sites in Western Australia.

<table>
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<th>Sites</th>
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<th>Lower W coast</th>
<th>Central W coast</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Tropical</td>
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<td>16</td>
<td>3</td>
<td>5</td>
<td>15</td>
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<td>Temperate</td>
<td>8 9</td>
<td>9 7</td>
<td>6 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Endemics</td>
<td>15</td>
<td>18</td>
<td>21</td>
<td>26</td>
<td>23</td>
<td>24</td>
<td>17</td>
</tr>
</tbody>
</table>

% of Total Species from Site | 28 | 32 | 33 | 23 | 28 | 16 | 27 | 12 | 10 | 6 | 5 | 3 | 3 | 0.9 | 0.7 | 0.3 | 6 | 2 |
Shark Bay and Houtman Abrolhos—also had moderate numbers of subtropical and temperate species. The site with the lowest number of species was Northeast Kimberley (site 20), which at 46 species was slightly lower than the numbers found at the temperate sites along the State’s south coast. The most speciose family was the Labridae with 116 species (10%) were found (Table 2). Most of the species are predominantly tropical but also include small numbers of subtropical and temperate species (Table 2).

Tropical species were found as far south as Albany (site 2), temperate species as far north as Shark Bay (site 8) and subtropical species between the Recherche Archipelago (site 1) and West Pilbara islands (site 11) (Table 3). A total of 427 tropical species (87% of the total) was recorded, whereas only 17 subtropical (3%) and 49 temperate species (10%) were found (Table 2). Most of the

Table 5 Most abundant species at three or more sites (abundance estimates: 1 = rare; 2 = occasional; 3 = frequent; 4 = abundant)

<table>
<thead>
<tr>
<th>Species</th>
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<th>Central W coast</th>
<th>Upper W coast</th>
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<th>Kimberley</th>
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<td>Lutjanidae</td>
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<td>Lutjanus carponotatus</td>
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</tr>
<tr>
<td>Acanthuridae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acanthurus grammoptilus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6 Number of species shared between seven regions of Western Australia (expressed as % of total species in each region)

<table>
<thead>
<tr>
<th>Regions</th>
<th>S Coast</th>
<th>Lower W coast</th>
<th>Cen. W coast</th>
<th>Upper W coast</th>
<th>NW coast</th>
<th>Atolls</th>
<th>Kimberley</th>
<th>Total Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>South coast</td>
<td>100%</td>
<td>97%</td>
<td>66%</td>
<td>40%</td>
<td>20%</td>
<td>1%</td>
<td>0%</td>
<td>68</td>
</tr>
<tr>
<td>Lower West coast</td>
<td>56%</td>
<td>100%</td>
<td>79%</td>
<td>64%</td>
<td>55%</td>
<td>31%</td>
<td>25%</td>
<td>118</td>
</tr>
<tr>
<td>Central West</td>
<td>29%</td>
<td>60%</td>
<td>100%</td>
<td>66%</td>
<td>78%</td>
<td>49%</td>
<td>36%</td>
<td>156</td>
</tr>
<tr>
<td>Upper West</td>
<td>13%</td>
<td>37%</td>
<td>51%</td>
<td>100%</td>
<td>93%</td>
<td>60%</td>
<td>46%</td>
<td>203</td>
</tr>
<tr>
<td>North West</td>
<td>5%</td>
<td>24%</td>
<td>46%</td>
<td>71%</td>
<td>100%</td>
<td>64%</td>
<td>46%</td>
<td>267</td>
</tr>
<tr>
<td>Atolls</td>
<td>0%</td>
<td>10%</td>
<td>32%</td>
<td>35%</td>
<td>50%</td>
<td>100%</td>
<td>25%</td>
<td>344</td>
</tr>
<tr>
<td>Kimberley</td>
<td>0%</td>
<td>21%</td>
<td>40%</td>
<td>67%</td>
<td>88%</td>
<td>66%</td>
<td>100%</td>
<td>141</td>
</tr>
</tbody>
</table>
tropical species are wide-ranging Indo-West Pacific species; 15 species are known only from the northern Australian area and six of these are considered endemic to Western Australia (Appendix 1). The subtropical component had the highest number of endemic species (Table 4), with only one species also inhabiting other parts of Australia. Most of the temperate species range into other southern States, but 10 are confined to Western Australia. Furthermore, endemic species comprised 23–53% of the fauna at each of sites 1–5 and 7 in the south west, 10–16% at sites 6, 8 and 9, but had reduced to negligible proportions by site 10 in the north west. In terms of the number of individuals, the endemic species were also among the most numerous in the southern half but were poorly represented in the northern half (species abundance is covered in more detail below). The most widespread species was the tropical labrid *Thalassoma lunare* which was recorded from 16 sites. The species with the most restricted distribution was the temperate endemic labrid *Pictilabrus brauni* (one site).

The figures presented in Table 3 indicate a significant variation in species numbers occurred between some adjacent survey sites. In the Kimberley, the offshore islands (site 19) had almost double the number of species recorded for the more inshore areas. Along the northwest coast, Ningaloo Reef (site 10) and West Pilbara islands (site 11) had noticeably more diverse faunas than the Monte Bello Islands (site 12) and Dampier Archipelago (site 13). In the central west and lower west coastal regions, one site in each (sites 6 and 4 respectively) had considerably higher numbers than adjacent areas (sites 7 and 5 respectively). All of these variations are probably due to ecological differences which are discussed in more detail below.

**Relationships**

Apparent relationships in the dataset (Appendix 1) were explored using the hierarchical classification analysis described above in the Methods section. The dissimilarity dendrogram for faunal assemblages at the 20 survey sites is illustrated in Figure 2. Two main clusters are apparent at the 0.75 level of dissimilarity: the first includes all locations between the Recherche Archipelago (site 1) and Kalbarri (site 7), excluding the Houtman Abrolhos (site 6), and the second encompasses all locations from Shark Bay (site 8) northwards but including the Houtman Abrolhos.
At a level of dissimilarity of approximately 0.7, the northern group forms two more clusters, one consisting of the Kimberley (sites 17-20) and the other comprising sites extending from the Houtman Abrolhos to Ashmore Reef (sites 6-16). The latter cluster can be further differentiated into two assemblages at a dissimilarity level of about 0.5, one consisting of the offshore atolls (sites 14-16) and the other of upper west coast and northwest coast sites (sites 8-13) but also including one site on the central west coast (site 6). This suggests that four major assemblages of shallow reef fishes (at the 0.65 level of dissimilarity) can be recognised in Western Australia (see Figure 2):

1. Southwest assemblage
2. Northwest assemblage
3. Offshore atolls assemblage
4. Kimberley assemblage

The southwest assemblage, which overlaps the northwest assemblage on the central west coast between the Houtman Abrolhos and Kalbarri (Fig. 2), consists mainly of temperate species whereas the other three assemblages are predominantly tropical (Table 3). The southwest assemblage can be further differentiated into two groups at a dissimilarity level of 0.55, one consisting of Kalbarri (site 7) and the other of the south coast and lower southwest sites. The latter can be further separated into two clusters at the 0.35 level, south coast (sites 1–3) and lower west coast (sites 4 and 5). The Kalbarri site is clearly differentiated from the other sites mainly because of a prominent reduction in temperate species (only 12 of 47 species were recorded for Kalbarri [Table 3]). The northwest assemblage can be separated into two groups at the 0.40 level, one consisting of a central to upper west coast cluster (sites 6, 8 and 9), the other of a northwest coast cluster (sites 10–13). The offshore atoll assemblage at a level of 0.25 consists of two groups, one comprising the Rowley Shoals and the other of Scott, Seringapatam and Ashmore Reefs. The Kimberley assemblage is composed of three groups at the 0.4 level; these correspond to the southwest, north and northeast regions of the Kimberley.

For comparison, Figure 3 presents a dendrogram based on presence-absence data only. Four main assemblages are still evident (at the 0.55 level of dissimilarity). The only major differences are in the

![Figure 3](image_url)
northwest and Kimberley assemblages. In the former, Houtman Abrolhos (site 6) clusters separately from the rest of the upper west and lower northwest coast sites (sites 8–13), instead of being grouped with Shark Bay (site 8) and Coral Bay (site 9) as in Figure 2. In the Kimberley assemblage, the north Kimberley (offshore) (site 19) is distinguished from a group of the other three Kimberley sites, whereas in Figure 2, the southwest Kimberley (site 17) clusters separately from the others. In addition, most clusters in Figure 3 are somewhat lower in dissimilarity than the same clusters in Figure 2 (i.e., utilising presence-absence data indicated a slight increase in similarity for each cluster when compared to data usage incorporating relative abundance).

Most abundant species

Within the four main assemblages described above, species-groups characterising the fauna of each site were identified. These are comprised of species that were usually observed in very large numbers and were also the most widespread at each site (Hutchins [1994] referred to these as representing the ‘faunal signature’ of an area). They provide a quick and reasonably accurate guide to the composition of the fishes at each site. These species-groups are described below, following the hierarchical arrangement depicted in Figure 2. Additional information on other species relevant to the site is also included.

Southwest Assemblage

Sites 1, 2 and 3 (Israelite Bay to Cape Naturaliste). The south coast consists mainly of temperate species with increasing numbers of subtropicals from east to west. The most abundant are the temperate endemic species such as the pomacentrids Chromis klunzingeri and Parma nuculochi, and the labrids Pseudolabrus biseriatis and Dotalabris alleni. Non-endemic temperate species like the labrids Austrolabris maculatus, Notolabrus parilus, and Ophthalmolepis lineolatus are also abundant, as are the pempheridid Pempheris klunzingeri and scorpidid Scorpaena aequipectinis. The endemic subtropical labrids Coris auricularis and Halichoeres brownfieldi become more numerous westwards. One temperate species, the non-endemic cheliodactylid Cheilodactylus nigripes, is in moderate numbers in eastern areas but these reduce westwards. A few tropical species were recorded, including the labrid Anampses geographicus at Albany, and the haemulid Plectorhinchus lutescens and mullid Parupeneus spilurus from the capes area, but all were in low numbers.

Sites 4 and 5 (Perth to Port Denison). The lower west coast is dominated by a combination of subtropical and temperate species. The most abundant subtropicals, all of which are endemic, are the labrids Coris auricularis and Halichoeres brownfieldi, the pomacentrids Chromis klunzingeri and Parma occidentalis, the scorpidid Neotypus obliquus and the kyphosid Kyphosus cornelii. The pomacentrid Parma maculolochi and labrid Pseudolabrus biseriatis (both temperate endemics) are equally abundant, as are the labrid Notolabrus parilus, kyphosid Kyphosus sydneyanus, and scorpidid Scorpaena aequipectinis (all temperate non-endemics). The subtropical endemic labrid Chaetodon rubescens becomes more numerous northwards. Tropical non-endemic species such as the mullid Parupeneus spilurus, the pomacentrids Abudedefduf vaigiensis, A. sexfasciatus, Pomacentrus milleri, and Stegastes obreptus, and the labrids Anampses geographicus, Thalassoma lunare and T. lutescens also become more numerous northwards; they sometimes occur in prominent numbers seasonally, but none is abundant year round.

Site 7 (Port Gregory to Kalbarri). The central west coast (inshore) is characterised by subtropical endemics such as the pomacentrid Parma occidentalis, the kyphosid Kyphosus cornelii, and the labrids Coris auricularis and Halichoeres brownfieldi. The temperate non-endemic labrids Notolabrus parilus and Austrolabris maculatus are also very numerous. Some tropical non-endemic species, such as the pomacentrids Pomacentrus milleri and Abudedefduf bengalenisis and the mullid Parupeneus spilurus, also were observed in high numbers; however, most of the other tropical species were recorded infrequently.

Northwest Assemblage

Site 6 (Houtman Abrolhos). The central west coast (offshore) is dominated by tropical non-endemic species, although a number of subtropical endemic species are also abundant. The most abundant tropical species are the pomacentrids Pomacentrus milleri and Abudedefduf sexfasciatus, and the labrids Stethojulis striiger, Thalassoma lunare, T. lutescens and Anampses geographicus. The most numerous subtropical endemics are the labrids Chaetodon rubescens, Coris auricularis, and Halichoeres brownfieldi, the pomacentrids Chromis westaustralis and Parma occidentalis, and the kyphosid Kyphosus cornelii. The temperate non-endemic kyphosid Kyphosus sydneyanus is also abundant. Many tropical species were recorded for the area but other than those mentioned above, most were observed in low to moderate numbers only.

Sites 8 and 9 (Shark Bay to Coral Bay). The fishes of the upper west coast are predominantly tropical but some of the most common species are subtropical, especially in the Shark Bay area. Tropical species that are abundant (all non-endemic) include the labrids Thalassoma lunare, T. lutescens, Stethojulis bandanensis, Halichoeres nebulosus, and Anampses geographicus, and the pomacentrids Abudedefduf sexfasciatus, A. vaigiensis,
Chromis atripectoralis, Pomacentrus milleri, P. coelestis and Stegastes obreptus. The following endemic subtropicals are abundant in the Shark Bay area, their numbers reducing northwards: the pomacentrid Chromis westaustralis, the labrids Halichoeres brownfieldi, Choerodon rubescens, Coris auricularis and Suezichthys cyanolacmus, and the kyphosid Kyphosus cornelli.

Sites 10 and 11 (Ningaloo to West Pilbara islands). The lower northwest coast possesses a mainly tropical fauna (a few subtropical species occur here in low numbers). The most abundant species are the labrids Thalassoma lunare, T. lutescens, Coris caudimacula, Halichoeres nebulosus and Stethojulis bundanensis, the pomacentrids Abudefois sexfasciatus, Chromis atripectoralis, Neopomacentrus azysron, Pomacentrus coelestis, Pomacentrus mulluccensis, P. milleri, P. waudi, Plectroslaphodon lacrymatus, the caesionids Caesio cuning and Pteroceros digramma, and the acanthurid Acanthurus grannoptilus. This area has the most diverse fish fauna of mainland Western Australia, the richest areas being around offshore islands such as the Muiron and Serrurier Islands. However the diversity reduces significantly to the north east as the waters become more turbid.

Sites 12 and 13 (Monte Bello Islands and Dampier Archipelago). The central northwest coast has a tropical fauna, the most abundant species being the pomacentrids Abudefduf bengalensis, Acanthochromis polyacanthus, Dischistodus darwinienis, Neopomacentrus azysron and Pomacentrus milleri, the labrids Choerodon cyanodus and Halichoeres nigrescens, the lutjanid Lutjanus carponotatus, the chaetodontid Chaetodon aureofasciatus, and the acanthurid Acanthurus grammoptilus (all are non-endemic). The endemic serranid Epinephelus biolatus and endemic labrid Choerodon cautorema are also very numerous in the southwest Kimberley, but both were rarely found to the north of Cape Leveque. Some species like the pomacentrids Pomacentrus coelestis and Stegastes obreptus, the labrid Labroides dimidiatus and the serranid Epinephelus fasciatus are more numerous in the offshore north Kimberley (site 19), than the other more inshore sites.

The dominant family of these species-groups is the Pomacentridae with 28 species that are abundant (Appendix 1) in one or more areas. This is followed by the Labridae (21 species), Acanthuridae (4), and Caesionidae (3). The remaining families with abundant taxa (Serranidae, Lutjanidae, Lethrinidae, Scorpididae, Kyphosidae, Pempheridae, Chaetodontidae, and Odonidae) are represented by 1-2 species only. The most abundant species is the pomacentrid Pomacentrus milleri which was recorded in large numbers from 9 sites. Other species that were abundant at three or more sites are listed in Table 5. This spread includes 16 tropical, 3 subtropical, and 7 temperate species. Non-endemics account for 20 species and endemics for 6.

The numbers of species shared between each of the seven geographic regions is presented in Table 6 (expressed as a percentage of the species total for each region). Each line of data indicates a species diversity gradient for the region listed in the first column; this shows the percentage similarity between the relevant region and the other six. For example, 79% of the 118 species recorded for the offshore north Kimberley (site 19), than the other more inshore sites. The most striking gradient concerns the offshore atolls. Only 50% of its 344 species reach mainland Western Australia (in the northwest coast region), and only 25% are shared with the nearby central west coast but only 25% with the Kimberley. The most striking gradient concerns the offshore atolls. Only 50% of its 344 species reach mainland Western Australia (in the northwest coast region), and only 25% are shared with the nearby central west coast but only 25% with the Kimberley. This suggests that many atoll species are unable either to tolerate the more inshore conditions of mainland waters (e.g., due to the higher turbidity) or to disperse across the gap separating the sites but not at the Monte Bello Islands (the pomacentrid Neopomacentrus filamentosus and the labrid Halichoeres nigrescens for example).
them. Another noteworthy gradient involves the upper west coast region. Here, only 51% of its 203 species were found at the adjacent central west coast region to the south, whereas 93% were recorded for the nearby northwest coast region to the north. This shows a prominent loss of species between the upper west coast and its neighbouring region to the south.

Discussion

Previous studies of the shallow reef fish fauna of Western Australia (Wilson and Allen, 1987; Hutchins, 1994) indicate a close similarity with the faunas of other parts of Australia. The tropical component shares many species with north-eastern Australia (as well as other parts of Southeast Asia and beyond) and the temperate component includes a prominent number of species that are found across the whole southern portion of Australia. The two components overlap on the west coast in an area often referred to by marine biogeographers as the "western overlap zone" (Wilson and Gillett 1971); this ranges approximately from Albany on the south coast to Shark Bay on the west coast. Here tropical species near the southern end of their ranges share reefs with temperate species that are approaching their northern limits. However, this region is also inhabited by another small group of fishes that is more subtropical in distribution. Comprising mainly endemic Western Australian species, the subtropical component provides many of the most abundant reef fishes in the region. Numerous temperate endemic species are also abundant here and together with the subtropical taxa, give a distinctive western character to the fauna. This caused Hutchins (1994) to determine that this region should be included in a separate southwest biogeographical zone named the Leeuwin Province (modified after Hatcher, 1991). This was essentially a western counterpart of the Peronian Province of eastern Australia, the latter region being referred to by Wilson and Gillett (1971) as the "eastern overlap zone".

Although the present investigation was confined to a subset of the reef fish fauna of Western Australia, any perceived distributional patterns of the 18 families studied here should reflect patterns of the fauna as a whole. The data in Table 3 clearly indicate that a prominent tropical fauna overlaps a smaller temperate fauna on the west coast, and that a still smaller subtropical component also shares this overlap zone. Furthermore Table 4 suggests that the southwest region (sites 1 to 7 but not including the Houtman Abrolhos, site 6) is inhabited by a fauna that has a relatively high proportion of endemics (range 23–33%). Sites 6, 8, and 9 have moderate numbers of endemics (10–16%), but from Ningaloo Reef (site 10) northwards, the indigenous species have relatively little impact (0–6%). The majority of these endemics belong to the subtropical component. However, the hierarchical analysis of the data suggests, at a level of dissimilarity of 0.75, that only two main groups of reef fishes are present, one a predominantly temperate fauna occupying the southwestern corner and the other a mostly tropical fauna in the northern two thirds of the State. There is no evidence of a separate subtropical cluster, or of a wide overlap zone on the west coast.

Working with molluscs, both Wilson and Gillett (1971) and Wells (1980) provided evidence that an extensive zone of intermixing between the tropical and temperate faunas exists along the west coast of Western Australia. This zone was also addressed in the more wide-ranging treatment of the marine fauna by Morgan and Wells (1991). All refer to the influence of the endemic species in this overlap zone. However, Veron and Marsh (1988), using a hierarchical classification similar to that employed in the present study showed only a narrow overlap of reefal (northern) corals and non-reefal (southern) corals in the central west coast area. There seems little doubt, therefore, that the method of analysis employed here is responsible for the apparently small size of the overlap zone. However, even though the general assumption of a two component reef fish fauna is favoured, the influence of the small subtropical element cannot be overlooked. It provides the majority of the endemic species in Western Australia, which also happen to be some of the most abundant.

Faunal divisions

Besides the partitioning of tropical and temperate components above, the hierarchical analysis of the dataset shows that the tropical fauna can be split into three major assemblages: offshore atolls, Kimberley coast and northwest coast. These divisions not only have a geographical basis, but ecological differences are also apparent.

The offshore atolls are surrounded by waters of very low turbidity, and have the best-developed coral reef communities in Western Australia (Wilson, 1994). They possess the highest fish diversity of any region, although a rather prominent species gradient occurs from north to south. Ashmore Reef, which is the northernmost, has 290 species, whereas Scott and Seringapatam Reefs possess 271 species, and the Rowley Shoals at the southern end of the atoll chain has 228 species. The fish faunas of all three are very similar, but the southern end of the atoll chain has 228 species.

The fish faunas of all three are very similar, but the southern end of the atoll chain has 228 species.
into mainland waters of the State. However, a number of transient visitors from the atolls have been recorded at Ningaloo Reef and the West Pilbara islands, possibly reaching these areas via the Leeuwin Current (described more fully below), and therefore helping to boost species numbers.

By comparison, coral communities in the Kimberley are far less extensive than at the offshore atolls. While moderate numbers of coral reef inhabitants were found in inshore waters where the turbidity was high, the greatest diversity occurred on the reefs surrounding the more offshore islands. The relatively clearer waters there allow a much stronger representation of reef fishes. A few transient visitors from the atolls were also found at these offshore islands but were always in low numbers. However, some Ashmore Reef species, such as the pomacanthid Chaetodontoplus mesolencus, were reasonably numerous in parts of the Kimberley. In contrast, a number of species from the southwest Kimberley (e.g., the endemic serranid Epinephelus bilobatus and endemic labrid Choerodon cauteroma) were rarely found to the north of Cape Leveque.

Within the northwest assemblage, coral communities are also extensive, but generally decrease in diversity southwards. However, reef fish diversity at the Monte Bello Islands and the Dampier Archipelago was found to be considerably lower than that of Ningaloo Reef and the West Pilbara islands. Many of the additional species in the latter two areas are typical inhabitants of the offshore atolls, and possibly dispersed south via the Leeuwin Current. Furthermore, Hutchins (1994, 1999) suggested that water conditions at Ningaloo Reef are more oceanic than at the Monte Bello and Dampier Archipelago, and this could account for the higher fish diversity at the former area. Ningaloo Reef certainly lies closer to the edge of the continental shelf than the other two, which would ensure that more current borne larvae would have a better chance of reaching its reefs. In addition, a 1996 survey conducted on the outer reefs of the West Pilbara islands (Hutchins, Mooi, and Gill, unpublished data) found additional atoll species that had not been recorded for mainland waters before.

The second group of the northwest assemblage – the central and upper west coast sites 6, 8 and 9 – show both a reduction in tropical reef fishes and an increase in subtropical and temperate species with increasing latitude. However, the fauna remains predominantly tropical and all sites have extensive coral communities. Nevertheless, at the Houtman Abrolhos (site 6), macroalgal communities are much more evident than further north, and compete successfully with corals for the available substrate (Hatcher, 1991), especially on the more exposed reefs along the western margin. This represents a significant divergence from a reef ecology dominated by corals, resulting in less favourable conditions for coral reef dwellers.

To the south of the Houtman Abrolhos, macroalgal communities dominate most shallow reefs and tropical reef fish diversity is much reduced. Notwithstanding, coral communities are rather prominent in some areas, particularly near Jurien Bay in site 5 and at Rottnest Island in site 4. They have noticeable populations of tropical reef fish, although numbers tend to fluctuate from year to year (Hutchins, 1994; Hutchins and Pearce, 1994). Furthermore, on the south coast, some prominent monospecific stands of tropical coral occur, but attract few tropical reef fishes.

Impact of Ocean Currents

Many papers over the last 20 years (e.g., Wilson and Allen, 1987; Pearce and Walker, 1991; Hutchins, 1994) have referred to the effects of ocean currents on the Western Australian biota, particularly the Leeuwin Current. This warm current has been implied as the vehicle for transporting fish larvae from northern waters southwards (Hutchins and Pearce, 1994; Hutchins, 1997a). There is little doubt that it affects the whole western coastline and is responsible for the spread of tropical species into temperate waters. Furthermore, recent studies (McGowran et al., 1997; McNamara, 1999) suggest that this current—or an ancestral form of it—may have been affecting the State’s coastal waters and its flora and fauna since the Eocene. Perhaps the present day patterns of biotic distribution reflect some of the evolutionary history of the Leeuwin Current.

The Leeuwin Current is a poleward flowing body of warm water in the eastern Indian Ocean. It originates as a southerly continuation of what has become known as the Indonesian throughflow, which in turn is sourced from the central Pacific Ocean. There, strong southeast trade winds force waters of the Southern Hemisphere to the west. These warm waters push through the island passages and eventually exit the Indonesian archipelago in the tropical Indian Ocean. Some of this water flows south along the western margin of Australia to form the Leeuwin Current. Depending on the atmospheric pressure gradient between the Pacific and Indian Oceans (which gives rise to the Southern Oscillation), conditions may favour either a strong or weak current (these are associated with phenomena known either as La Niña or El Niño respectively). The flow of this eastern boundary current becomes more pronounced in late summer to early autumn, continuing through winter before waning in spring. It tends to follow the edge of Western Australia’s continental shelf, with gyres pushing across the shelf into coastal waters,
especially in the southern half. Off Cape Leeuwin in the States’ south west, the current changes direction and heads east towards South Australia, sometimes reaching as far as Tasmania (as the East Bight Current [Pearce and Cresswell, 1985]). Therefore, this current has the potential to distribute propagules of marine organisms from Indonesia to north-western Australia, as well as picking up others from breeding populations along the State’s northwest and west coasts for dispersal southwards and eastwards. The primary effect of the Leeuwin Current, like that of the East Australian Current and other poleward flowing boundary currents around the world (Hutchins, 1991), therefore, is to extend the range of the tropical fauna southwards, even into temperate areas. Furthermore, it also provides the means to disperse eggs and larvae of subtropical biota to the southern coastline of Australia. On the other hand, counter-currents flowing inshore of the Leeuwin Current are believed to be responsible for the dispersal of temperate and subtropical species to the north (Hutchins, 1994; Taylor and Pearce, 1999).

The Leeuwin Current is thought to have evolved in the middle Eocene when changes to current flow in the eastern Indian Ocean were caused by the accelerated opening of the oceanic gap between Australia and Antarctica (McGowan et al., 1997). Furthermore, the flow has since been episodic rather than continuous, following the pattern of glacial and interglacial events. Thus the evolution of the marine fauna of Western Australia could have been influenced by this variation in current flow.

Many of the largest families of reef fishes (e.g., Pomacentridae and Labridae) are considered by some workers to have evolved in the tropical Tethys Sea, an ancient ocean that existed between the two supercontinents of Laurasia and Gondwana from the Cretaceous to the Miocene (Hopper et al., 1996). The subsequent dispersal of these taxa is represented today by species diversity gradients from a central area of high diversity (e.g., Indonesia) to marginal areas (Briggs, 1999). In Western Australia, these families have contributed many of the endemic species in our waters, probably evolving into new forms as they spread southwards. These evolutionary events might be linked to fluctuations — “ebb and flow” events — of an ancient Leeuwin Current. During extended periods of strong flow, the conditions would have been more tropical and during periods of weak flow more temperate. Species inhabiting marginal areas therefore could have been isolated by a changing current regime. Repeated isolations of these taxa may have eventually allowed them to achieve reproductive isolation, and finally speciation. Many of the subtropical endemic species in Western Australia are apparently closely related to tropical taxa (e.g., the labrids Thalassoma septemfasciata, Halichoeres bрюnfieldi and Choerodon rubescens and the pomacentrid Chromis westaustralis), but others (e.g., the chelodactylid Cheilodactylus rubrolabialis and the pomacentrid Parma occidentalis) apparently have close temperate relatives, which suggests a different path in the evolutionary story. However, until phylogenetic studies of the families in question are completed and published, little can be said with confidence about such relationships, and therefore any associations with the flow of the Leeuwin Current are only conjectural.

Hatcher (1991) in his study of coral reefs in the Leeuwin Current summed up the mechanism of the Leeuwin Current influence by noting the importance of gradients in three areas: physical and biotic environments, species diversity, and habitat diversity. He believed the Leeuwin Current affected all three, and, with due consideration of past events, could be tied to the pattern of reef and biotic development found in Western Australia today.

In the present study, the results indicate a gradient in species diversity along the State’s coastline that clearly has been impacted on by the Leeuwin Current. They demonstrate a connection between the Western Australian and Indonesian faunas, a relationship that commences in the northern offshore atolls (Allen, 1993b), and continues through a diminishing tropical fauna well into temperate seas. However, faunal differences between the offshore atolls and the mainland coasts, particularly in the Kimberley, suggest that gradients in the physical and biotic environments are acting as effective barriers to dispersal. Furthermore, the rather rapid southwards change in the reef habitat on the central west coast from one dominated by coral communities to one of increasing macroalgae is closely matched by a change in the reef fish fauna. The tropical fishes that held sway on the northern reefs now have to contend with a stronger temperate influence. In addition, a small though faunistically important group of subtropical endemic species is prominent there, and contributes much to the uniqueness of the area.

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REFERENCES


Rapid censusing technique for reef fish


Manuscript received 15 November 1999; accepted 8 August 2000.
### Appendix 1

Abundance estimates of species recorded from 20 sites in Western Australia (abbreviations and symbol in second column: S = subtropical; T = temperate; blank = tropical; * = WA endemic) (abundance estimates: 1 = rare; 2 = occasional; 3 = frequent; 4 = abundant; see also Methods section)

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### Rapid censusing technique for reef fish

#### Site No. | South coast | Lower W coast | Central W coast | Upper W coast | NW coast | Atolls | Kimberley
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1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20

- **P. squamipinnis**
- **P. luka**
- **Rainfordia opercularis**
- **Variola albinarginata**
- **Variola louti**

#### CAESIONIDAE

- **Caesio caerulea**
- **C. cuning**
- **C. lunaris**
- **C. teres**
- **Pterocaesio digramma**
- **P. pisang**
- **P. tile**
- **P. trilineata**

#### LUTJANIDAE

- **Apliareus furca**
- **Aprion virens**
- **Lutjanus argentimaculatus**
- **L. bipinnatus**
- **L. bohar**
- **L. carponotatus**
- **L. decussatus**
- **L. fulviflamma**
- **L. fulvius**
- **L. gibbus**
- **L. kasimia**
- **L. lemniscatus**
- **L. lutjanus**
- **L. monostigma**
- **L. quinquelineata**
- **L. rubulatus**
- **L. russelli**
- **L. sebae**
- **L. vitta**
- **Macolor macularis**
- **M. nigra**
- **Symphysodrithys splinurus**
- **Symphorhinus nematophorus**

#### HAEMULIDAE

- **Diagramma labiosum**
- **D. pictum**
- **Plectrohelinus chaetodonoides**
- **P. flavomaculatus**
- **P. gibbosus**
- **P. lineatus**
- **P. multivittatum**
- **P. orientalis**
- **P. polylepis**
- **P. unicolor**

#### LETHRINIDAE

- **Gnathiodentex auricolatus**
- **Gymnocranius grandoculis**
- **Lethrinus atkinsoni**
- **L. crytilacantus**
- **L. crytilopterus**
- **L. geniculatus**
- **L. harak**
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The table lists species of fish found in various coastal locations, with Site No. 1 to 19 representing different coastal areas and Site No. 20 representing Kimberley. Each row indicates the presence of a species in a particular coastal location, with numbers indicating the frequency of occurrence.
## Rapid censusing technique for reef fish

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Rapid censusing technique for reef fish

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| Siphonoglyphus beddomei | T 4 4 3 2 1 |                 |                 |               |          |        |           |
| S. caninus | T 3 2 2 1 1 |                 |                 |               |          |        |           |

**ACANTHURIIDAE**

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**MONACANTHIDAE**

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| Aluterus scriptus | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Amanses scobin | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Brachaluteres jacksonianus | T | 1 | 1 | 2 | 1 | 1 | 1 |
| Cantherhines dumerilii | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| C. fronticinctus | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| C. pardalis | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Exbalichthys cyanoura | T | 2 | 1 | 1 | 1 | 1 | 1 |
| E. mosaicus | T | 1 | 1 | 1 | 2 | 1 | 1 |
| Menschens gaiti | T | 3 | 3 | 3 | 2 | 3 | 1 |
| M. flavolineata | T | 3 | 3 | 3 | 2 | 3 | 1 |
| M. hippocrepis | T | 3 | 3 | 3 | 2 | 3 | 1 |
| Monacanthus chinensis | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Oxymonacanthus longirostris | T | 1 | 2 | 2 | 1 | 1 | 1 |
| Paraluteres pronus | 1 | 1 | 1 | 1 | 2 | 1 | 1 |
| Pseudojubinichthys granulatus | T | 1 | 2 | 2 | 1 | 1 | 1 |

J.B. Hutchins
The Bilby *Macrotis lagotis* (Marsupialia: Peramelidae) in south-western Australia: original range limits, subsequent decline, and presumed regional extinction

Ian Abbott
CALMScience Division, Department of Conservation and Land Management, Locked Bag 104, Bentley Delivery Centre, Western Australia 6983, Australia

Abstract - Knowledge of the original south-western geographic range limits of the Bilby *Macrotis lagotis* in Western Australia, before its regional decline and apparent extinction, is currently underpinned by only six museum records, including three from near Bridgetown. The collector of one of the latter specimens in 1933 was interviewed, clarifying the source localities of these specimens. A further 155 residents, mostly aged 70 years or more, were interviewed, resulting in additional localities based on observations. A search of published and unpublished historical sources also revealed several acceptable records. This information was then coupled with detailed 1: 250 000 vegetation complex maps prepared in 1998 for the Regional Forest Agreement to produce a map of the inferred original distribution of the Bilby in south-western Australia. Bilbies appear to have occurred in suitable areas of open forest and woodland in the northern and eastern jarrah forests, west to about Chittering, Childlow, Marradong, Bowelling, Boyup Brook and Bridgetown. The main southern limit appears to have been Warren River at Quilliben forest block (along valleys containing sandy soils), Perup River near Deeside, Hay River near Forest Hill, and north of Porongurup Range. Bilbies also occurred, apparently sporadically, farther southwest at Margaret River, along the Blackwood River between Darradup and Alexandra Bridge, near Lake Jasper, near Dombakup, and between Kent River and Denmark.

Factors possibly implicated in the extinction of the Bilby in southwestern Australia are reviewed. Although drought, disease, trapping, and distribution of poison baits for rabbit control reduced population numbers of the Bilby, the coup de grâce was delivered by the arrival of the Fox in the late 1920s/early 1930s. The last specimens were collected in 1935, though a few populations might have persisted very locally until the 1970s or even 1980s.

Current proposals to re-introduce the Bilby to public land in its inferred former range will serve to test the hypothetical original distribution of the Bilby, prior to the arrival and establishment of the Fox.

INTRODUCTION

The Bilby, *Macrotis lagotis* (Reid, 1837), is a nocturnal, rabbit-sized marsupial with silky blue-grey fur, long naked ears, a pointed pink snout, and a long tail black near the base, white near the tip, and carried flag-like off the ground (Johnson, 1995). It lives in a burrow 1-2 m deep and with a single entrance, with one animal to a burrow, and there may be many burrows in an area of c. 1 ha (Ride, 1970). Its scientific description in 1837 was based on a south-western Australian specimen collected from "Swan River" (Thomas, 1888: 225; Mahoney and Ride, 1988). The Bilby originally occurred widely throughout the interior of Australia, being absent from the higher rainfall subcoastal zone (Southgate, 1990) except near Perth (average annual rainfall = 853 mm) and Bridgetown (856 mm). These somewhat anomalous, though biogeographically interesting, former range limits in south-western Australia are, however, supported by six voucher specimens held in the Western Australian Museum (WAM), Perth (Kitchener and Vicker, 1981).

The first part of this paper addresses the question of how much more widely the Bilby may have occurred in the lower southwest of Western Australia, particularly in the forests, prior to its regional decline and apparent extinction. Christensen and Kimber (1977) did not record the Bilby for State Forest, noting, however, that their list "probably does not include all the mammals that live [or lived] in the forest areas". The Bilby was also not listed as occurring [or having occurred] in the northern jarrah forest (Nichols and Muir, 1989) or southern forests (Christensen et al., 1985), although Christensen (1992) considered that its habitat in the Blackwood valley was now largely
Figure 1  Source localities of voucher specimens and observational records of the Bilby in the lower southwest sector of Western Australia. Also shown is the original extent of forest before European settlement and the inferred southwest boundary of the geographic range of the Bilby. The term 'museum record' refers to a specimen that was either not retained by, or was retained but cannot now be located in, WAM.
The Bilby *Macrotis lagotis* in south-western Australia
cleared for farming. Abbott and Christensen (1994) stated that this species, on the basis of museum specimens, was not known to have occurred in State Forest.

Several approaches are used in order to elucidate the extent of the original geographic range limits of the Bilby in south-western Australia. The first is linked to using, and where possible clarifying, label data of museum specimens. The second is based on oral history (in this case based on interviews with farmers and other residents mostly older than 70 years), a technique used successfully by Sanders (1991) to document environmental change in wetlands in the Western Australian wheatbelt. The third approach is based on a search of numerous local histories (see Richards, 1993), the relevant zoological literature, and Department of Conservation and Land Management (CALM) files on the Bilby.

The second part of this paper analyses the possible causes of the decline of the Bilby in south-western Australia. This section integrates concepts from the scientific literature with observations and interpretations of landholders present before, during and after Bilby populations collapsed in the 1930s.

**METHODS**

Locality Data

All museum and other records of the Bilby from lower south-western Australia (Figure 1) were obtained from several sources. Specimen data were extracted from Kitchener and Vicker (1981: 156–7) and checked against specimen labels, catalogue entries, and letter archives in the Western Australian Museum. Published historical records were extracted from Krefft (1867), Haddleton (1952), Spencer (1966: 75), Jenkins (1974), de Burgh (1976), Kitchener *et al.* (1978: 68), and Douglas (1980). Many other historical sources were also searched, but without success. I also contacted Noongars (south-western Australian Aborigines) but this did not elicit any information (N. Nannup, personal communication 1999; C. Birdsall of the Noongar Land Council, personal communication 1999).

Most information was obtained by interviewing in the period 1997–2000 farmers and other residents 70 or more years old. I took great care to avoid asking leading questions. My interview technique was first to introduce myself and explain how I obtained the contact’s name, then to explain my purpose (to discover more information about the occurrence of native fauna earlier this century), and next to work through a list of conspicuous mammal and bird species. The term ‘Dalgyte’, the Noongar name for *Macrotis lagotis*, was first mentioned in this context. If the interviewee was familiar with the term Dalgyte, I then ascertained whether this term was applied to the correct species by asking him or her to describe the appearance of the animal and where it lived. I expected a clear recollection of the species’ characteristic ears, muzzle, fur, tail and burrowing habit. Details were then sought of the interviewee’s recollections of its local distribution, abundance, habits, year when last observed, and why it disappeared. During these conversations, mindful of ongoing media reports of thylacines, I adopted a tone of amiable scepticism rather than one of naivité and credulity.

If the interviewee did not know the term Dalgyte, I briefly described the animal and its burrowing habit in order to elicit a recollection. In most cases, if the term Dalgyte was not known, the interviewee had no personal experience of *M. lagotis*.

These records were then mapped (Figure 1), distinguishing between specimen-based records (Table 1) and observational records not supported by a voucher specimen (Table 2).

To provide context, other records (museum specimens, observations made by or reported to interviewees) adjacent to the forest were also mapped. These are referenced in Table 2. Eyewitness accounts of the ecology and behaviour of the Bilby in south-western Australia from the period 1837–1935 have been collated in Appendix 1 from published records and unpublished reports.

Vegetation Units

The 306 vegetation complexes recognized and mapped in the Regional Forest Agreement area of south-western Australia (Mattiske and Havel 1998; Commonwealth and Western Australian Regional Forest Agreement Steering Committee 1998) were overlaid in a GIS with the Bilby records and those for which a Bilby record was present before, during and after Bilby populations collapsed in the 1930s.

**Darling Plateau Uplands**

Y5 Yalanbee 5. Mixture of Jarrah *Eucalyptus marginata* / Marri *Corymbia calophylla* open
Table 1  Museum specimens of *Macrotis lagotis* from lower south-western Australia with locality data, listed in chronological order. As noted in the text, the provenances of WAM specimens M703 and M787 are rejected on the basis of information present on the label or in the catalogue. WAM = Western Australian Museum; AM = Australian Museum; MV = Museum of Victoria; SAM = South Australian Museum; BM(NH) = Natural History Museum, London; OUM = Oxford University Museum; AMNH = American Museum of Natural History, New York; MCZ = Museum of Comparative Zoology, Harvard University; USNM = National Museum of Natural History, Smithsonian Institution, Washington DC. Only specimens with locality data are included.

<table>
<thead>
<tr>
<th>Specimen number</th>
<th>Label/Catalogue/Letter archives data</th>
<th>Other information</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM(NH) 41.1168</td>
<td>Northam. J. Gilbert. 1841</td>
<td>Male, Skin</td>
</tr>
<tr>
<td>BM(NH) 1939.3175</td>
<td>Warrup Stirling Range [= Warrungup on Salt River Rd on the north side of the Stirling Range and west of Chester Pass Rd]. J.T. Tunney. 30.5.1900</td>
<td>Female, Skin + skull</td>
</tr>
<tr>
<td>BM(NH) 1939.3176</td>
<td>Variously given as N. Magetup Salt River or Mt Magetup Salt R [= Magitup, south-west of Borden on the Pallinup River]. J.T. Tunney. 5.6.1900.</td>
<td>Male, Skin + skull</td>
</tr>
<tr>
<td>WAM M16100</td>
<td>Jerramungup (approx.). J.T. Tunney. 15.6.1900</td>
<td>Male, Skull</td>
</tr>
<tr>
<td>WAM M16101</td>
<td>Broomhill. T. Carter. 23.8.1905</td>
<td>Male, Skin + skull</td>
</tr>
<tr>
<td>WAM M16102</td>
<td>Kojonup (approx.). J.T. Tunney. 1905</td>
<td>Male, Skull</td>
</tr>
<tr>
<td>BM(NH) 681319</td>
<td>Arthur River [c. 30 km west of] Wagine. G.C. Shortridge. 23.6.1905</td>
<td>Male, Skin + skull</td>
</tr>
<tr>
<td>BM(NH) 681323</td>
<td>Woyaline, East Pingelly [c. 30 km east of Pingelly]. G.C. Shortridge + J.W. Bell. 30.3.1906</td>
<td>Female, Skin + skull</td>
</tr>
<tr>
<td>BM(NH) 681320</td>
<td>Woyaline, East Pingelly. G.C. Shortridge + J.W. Bell. 30.3.1906</td>
<td>Male, Skin + skull</td>
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<tr>
<td>BM(NH) 681324</td>
<td>Woyaline, East Pingelly. G.C. Shortridge + J.W. Bell. 30.3.1906</td>
<td>Female, Skin + skull</td>
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<tr>
<td>BM(NH) 681325</td>
<td>Woyaline, East Pingelly. G.C. Shortridge + J.W. Bell. 31.3.1906</td>
<td>Female, Skin + skull</td>
</tr>
<tr>
<td>BM(NH) 681321</td>
<td>Woyaline, East Pingelly. G.C. Shortridge + J.W. Bell. 1.4.1906</td>
<td>Male, Skin + skull</td>
</tr>
<tr>
<td>BM(NH) 681326</td>
<td>Woyaline, East Pingelly. G.C. Shortridge + J.W. Bell. 6.4.1906</td>
<td>Female, Skin + skull</td>
</tr>
<tr>
<td>BM(NH) 681322</td>
<td>Woyaline, East Pingelly. G.C. Shortridge + J.W. Bell. 16.4.1906</td>
<td>Male, Skin + skull</td>
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<tr>
<td>BM(NH) 681327</td>
<td>Woyaline, East Pingelly. G.C. Shortridge + J.W. Bell. 24.4.1906</td>
<td>Female, Skin + skull</td>
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<tr>
<td>OUM [537]</td>
<td>Woyaline, East Pingelly. G.C. Shortridge + J.W. Bell. 30.3.1906</td>
<td>Female, Skin + skull</td>
</tr>
<tr>
<td>OUM [541]</td>
<td>Woyaline, East Pingelly. G.C. Shortridge + J.W. Bell. 30.3.1906</td>
<td>Female, Skin + skull</td>
</tr>
<tr>
<td>WAM M16103</td>
<td>Gracefield. J.T. Tunney. 26.5.1907</td>
<td>Female, Skin + skull</td>
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<tr>
<td>AM M2001</td>
<td>Gracefield. [J.T.Tunney]. 11.8.1908</td>
<td>Male, Skin</td>
</tr>
<tr>
<td>AM M2002</td>
<td>Gracefield. [J.T.Tunney]. 11.8.1908</td>
<td>Male, Skin</td>
</tr>
<tr>
<td>AM M2019</td>
<td>Cranbrook. [J.T.Tunney]. 21.10.1908</td>
<td>Male, Skin</td>
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<td>USNM 154994</td>
<td>Broom Hill. J. Clarke. 23.10.1908</td>
<td>Male, Skin + skull</td>
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<td>WAM M16104</td>
<td>Gracefield. J.T. Tunney. 27.7.1909</td>
<td>Female, Skin + skull</td>
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<tr>
<td>WAM M16105</td>
<td>Gracefield (approx.). J.T. Tunney. 10.9.1908</td>
<td>Spirit, Skin + skull</td>
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<tr>
<td>MV C5876</td>
<td>Narrogin. Purchased H.J. Coles, Fremantle. 1911</td>
<td>Male, 'useless'</td>
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<tr>
<td>MCZ 17765</td>
<td>Broom Hill. 30.5.1910. Purchased from W.F.H. Rosenberg, donated in 1919 by T. Barbour</td>
<td>Male, Female, Skin + skull</td>
</tr>
<tr>
<td>WAM M6</td>
<td>Dalbingin [= Dlbning] E Narrogin. W. Bird. 11.10.1912</td>
<td>Male, 'useless'</td>
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<tr>
<td>WAM M234</td>
<td>Tammin. C. Blakely. 19.7.1915</td>
<td>Female, Skin + skull</td>
</tr>
<tr>
<td>WAM M334</td>
<td>Doodalakine, Mr Garrison. 30.6.1917</td>
<td>'useless', Female, Skin + skull</td>
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<tr>
<td>WAM M452</td>
<td>Mokerdillup. F. Foster. 26.1.1921</td>
<td>Footal, Spirit</td>
</tr>
<tr>
<td>WAM M456</td>
<td>Dangin. J.F. Jones. 17.2.1921</td>
<td>Skin + skull</td>
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<tr>
<td>AM M2955</td>
<td>Coorong (Corrigin), A.S. Le Soeuf. 28.4.1921</td>
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<td>Specimen number</td>
<td>Label/Catalogue/Letter archives data</td>
<td>Other information</td>
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<td>-------------------------------------</td>
<td>-------------------</td>
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<tr>
<td>AM M3101</td>
<td>Tenterden. E. Troughton &amp; J. Wright. 18.11.1921</td>
<td>Male. Skin + skull</td>
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<tr>
<td>WAM M610</td>
<td>Gingin. Mr Oliver of Bridgetown. -6.1923</td>
<td>'not kept'</td>
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<tr>
<td>WAM M637</td>
<td>Cunderdin. W. Blyth. 7.5.1924</td>
<td>Male. Skin + skull</td>
</tr>
<tr>
<td>WAM M638</td>
<td>Cunderdin. W. Blyth. 7.5.1924</td>
<td>Female. 'a young' Skin + skull</td>
</tr>
<tr>
<td>WAM M641</td>
<td>Cunderdin. W. Blyth. 17.5.1924.</td>
<td>Male. Skin</td>
</tr>
<tr>
<td>WAM M687</td>
<td>State School Clackline. E.W. Membrey. 1925</td>
<td>Male. Skin + skull</td>
</tr>
<tr>
<td>WAM M692</td>
<td>Malyalling via Wickepin. W. Howard. -3.1925</td>
<td>Male, 'a young Dalgyte from the pouch'</td>
</tr>
<tr>
<td>WAM M697</td>
<td>Cunderdin. W. Blyth. 19.5.1925</td>
<td>Male. Skin + skull</td>
</tr>
<tr>
<td>WAM M703</td>
<td>Upper Swan. E. Howard. 3.8.1925</td>
<td>Male. Skin + skull</td>
</tr>
<tr>
<td>WAM M718</td>
<td>Cunderdin. W. Blyth. -.9.1925</td>
<td>Female. Skin + skull</td>
</tr>
<tr>
<td>WAM M750</td>
<td>Cunderdin. Mr Menzel. -.12.1925</td>
<td>'a young Dalgyte...liberated'</td>
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<tr>
<td>WAM M787</td>
<td>Mounts Bay Road, run over near Swan Brewery. Mr Hillard. 13.7.1926</td>
<td>Male. Skin</td>
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<td>WAM M980</td>
<td>Chidlow. Mr Garland of Buckland near Northam. Catalogued 20.2.1928</td>
<td>Young animal</td>
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<td>WAM M1020</td>
<td>Cunderdin. J.J. Flanagan. 19.6.1928</td>
<td>Female</td>
</tr>
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<td>WAM M1021</td>
<td>Cunderdin. W. Blyth. 19.6.1928</td>
<td>Female</td>
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<td>WAM M1022</td>
<td>Cunderdin. J.J. Flanagan. 19.6.1928</td>
<td>'a young Dalgyte from pouch of M1020'. Spirit</td>
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<td>WAM M1023</td>
<td>Cunderdin. W. Blyth. 19.6.1928</td>
<td>'a young Dalgyte from pouch of M1021'. Spirit</td>
</tr>
<tr>
<td>WAM M1024</td>
<td>Cunderdin. W. Blyth. 19.6.1928</td>
<td>'a young Dalgyte from pouch of M1021'. Spirit</td>
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<tr>
<td>WAM M1025</td>
<td>Cunderdin. J.J. Flanagan. 20.6.1928</td>
<td>Male</td>
</tr>
<tr>
<td>WAM M1036</td>
<td>Cunderdin. W. Blyth. 6.7.1928</td>
<td>Female. Skull</td>
</tr>
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<td>WAM M1040</td>
<td>Cunderdin. W. Blyth. 25.7.1928</td>
<td>Female. Skin + skull</td>
</tr>
<tr>
<td>WAM M1041</td>
<td>Cunderdin. W. Blyth. 25.7.1928</td>
<td>'a young Dalgyte from pouch of M1040'. Spirit</td>
</tr>
<tr>
<td>WAM M1042</td>
<td>Cunderdin. W. Blyth. 25.7.1928</td>
<td>'a young Dalgyte from pouch of M1040'. Spirit</td>
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<tr>
<td>WAM M1044/1</td>
<td>Cunderdin. W. Blyth. 28.7.1928</td>
<td>Female. Skin + skull</td>
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<tr>
<td>WAM M1044/2</td>
<td>Cunderdin. W. Blyth. 28.7.1928</td>
<td>Female. Skin + skull</td>
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<td>WAM M1067</td>
<td>State School Bolgart. Master B. Pinkin. 10.9.1928</td>
<td>Male. Skin + skull</td>
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<td>WAM M1377</td>
<td>Bruce Rock. Mr Corvu. 1931</td>
<td>'caught near Bruce Rock by Mr Corvu who had it loose in his garden at Subiaco'. Road at side of railway between Subiaco and Daglish. Spirit</td>
</tr>
<tr>
<td>WAM M1391</td>
<td>Culham via Toodyay. Mr S.F. Howie. 27.4.1931</td>
<td>Male. Skin + skull</td>
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<tr>
<td>WAM M1399</td>
<td>Prestbury farm, Bridgetown. E.T. Moyes. 15.5.1931</td>
<td>Skull</td>
</tr>
<tr>
<td>WAM M1644</td>
<td>Wagin. H.S. Goldsmith. 11.8.1932</td>
<td>Male. Skin + skull</td>
</tr>
<tr>
<td>WAM M1749</td>
<td>Prestbury farm Bridgetown. H.S. Moyes. 19.5.1933</td>
<td>Male. Skin + skull</td>
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<tr>
<td>AM M1828</td>
<td>Narrogin. S. Larnach. 1933</td>
<td>Spirit</td>
</tr>
<tr>
<td>AM M20060</td>
<td>Narrogin. S. Larnach. 1935</td>
<td>Skull</td>
</tr>
<tr>
<td>WAM M1931</td>
<td>'The Nook', South Dale via Brookton. E. Wills. 19.2.1935. Eva Wills (b. 1921) advised me that this locality is 16 miles west of Brookton and is now owned by Neil Walker. This is Avon Location 8099/8086.</td>
<td>Male. Live animal sent to Zoo, thence to WAM 11.6.1935. Skin + partial postcranial</td>
</tr>
<tr>
<td>AMNH 74486</td>
<td>Gingin. F.W. Teesdale, 1926</td>
<td>Female</td>
</tr>
<tr>
<td>AMNH 74487</td>
<td>Gingin. F.W. Teesdale, 1926</td>
<td>Female</td>
</tr>
</tbody>
</table>
forest and Wandoo E. wandoo woodland on lateric uplands.

D4 Dwellingup 4. Jarrah / Marri open forest to woodland on lateric uplands.

DMg Dalmore. Mosaic of Wandoo / Marri woodland on deeper soils with open heath / lithic complex on shallow soils near granite outcrops.

DK1 Darkin 1. Jarrah / Wandoo / Marri woodland over Dryandra sessilis on uplands.

CO2 Collis 2. Jarrah / Marri / Banksia grandis open forest on low uplands, with some lithic complex associated with granite outcrops.

BE1 Bevan 1. Marri / Jarrah tall open forest on uplands.

BEY2 Bevan 2. Open forest of Jarrah / Marri / Banksia grandis on undulating uplands.

PP Perillup. Marri / Jarrah open forest / woodland on low undulating hills and low woodland of Melaleuca preissiana on depressions.

Darling Plateau Valleys

Mi Michibin. Wandoo / Jam Acacia acuminata woodland with some York Gum E. loxophleba on valley slopes and Rock Sheoak Allocasuarina huegeliana on granitic outcrops.

Bi Bindoon. York Gum woodland on slopes / Wandoo-Powderbark E. accedens woodland on breakaways and upper slopes.

LK2 Lukin 2. Wandoo woodland with some mixtures of Jarrah / Marri on valley slopes with occasional Flooded Gum E. rudis on valley floors.

BLF Balingup. Flooded Gum woodland on valley floors and Yarri E. patens / Marri woodland on footslopes with some Jarrah on lower slopes.

CC1 Catterick. Jarrah / Marri open forest mixed with Yarri (slopes), Flooded Gum and Banksia littoralis on valley floors.

NW2 Newgalup 2. Flooded Gum / Yarri woodland with occasional Wandoo on footslopes on valley slopes.

NWg1 Newgalup 1. Marri / Jarrah woodland on slopes, open heath on shallow soils near granites and Flooded Gum / Wandoo open forest on steeper slopes and valley floors.

DK2 Darkin 2. Mixture of Jarrah / Banksia woodland and Wandoo / E. drummondii / E. decipiens open woodland on lower slopes.

DK3 Darkin 3. Rock Sheoak / Jam woodland with occasional Flooded Gum / Wandoo near granite outcrops and E. astringens / Wandoo woodland on breakaways.

DK4 Darkin 4. Wandoo / Rock Sheoak / Jam woodland on slopes and Flooded Gum woodland on lower slopes.

BR Brockman. Marri / Wandoo woodland over Hakea prostrata and Acacia saligna on valley slopes.

WL Wilgarup. Marri open forest with some Jarrah on slopes and tall shrubland of Melaleuca species on valley floors.

YN1 Yannah. Mixture of tall open forest of Karri E. diversicolor / Marri / Yarri / Jarrah over Agonis flexuosa and A. juniperina in valleys.

LF Lefroy. Tall open forest of Karri / Marri on slopes and low woodland of A. juniperina and Callistachys lanceolata on lower slopes.

Darling Plateau Valley Floors and Swamps

DK5 Darkin 5. Casuarina obesa / Melaleuca spp. low woodland on low lying moister soils and Banksia prionotes / Marri / Flooded Gum / Jam woodland on sandy lunettes.

Darling Plateau Depressions and Swamps on Uplands

CL2 Corbalup 2. Jarrah / Marri open forest on low rises and low woodland of Melaleuca preissiana / B. littoralis on depressions.

Margaret River Plateau Valleys

W1 Wilyabrup. Tall open forest of Karri / Marri / Allocasuarina decussata / Agonis flexuosa on deeply incised valleys.

Blackwood Plateau and Plain Uplands

MP Milyearup. Open forest to tall open forest of Jarrah / Marri / Allocasuarina fraseriana with some Agonis flexuosa on less undulating slopes.

T Treeton. Woodland of Jarrah / Marri on undulating sandy slopes.

Blackwood Plateau and Plain Valleys

BK Blackwood. Marri / Jarrah open forest on slopes

Unicup Uplands

FH1 Frankland Hills. Woodland / low open forest of Jarrah with some Marri on uplands.

Scott Coastal Plain Valley Floors and Swamps

Swd Scott. Mosaic of sedgeland and closed heath with occasional Banksia on swampy depressions and stunted Jarrah, Banksia and Xyloomelum occidentale on low sandy rises.

Redmond Siltstone Plain Uplands

F Fernley. Mixture of woodland of Bullich E. megacarpa, woodland of Yarri, tall shrubland of Myrtaceae species with some sedgefield of Anarthria species on broad plains.

RESULTS

Museum Records

A search of WAM letter archives revealed little
Empirical & theoretical limits to the Inferred Distribution of the Bilby \textit{Macrotis lagotis} in Southwestern Australia

Figure 2 The hypothesized distribution of the Bilby. Also shown are the outline of forest blocks (management units which collectively constitute State Forest), and the RFA boundary (within which the vegetation complex information of Mattiske and Havel 1998 was used to model the distribution).
Table 2  Literature references, observational records, or other reports of the Bilby in southwestern Australia but from outside the RFA area. Listed chronologically by year of last observation, marked in bold.

<table>
<thead>
<tr>
<th>Locality</th>
<th>Years of Observation</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northam</td>
<td>Museum specimens (Natural History Museum, London); two of which were collected by Gilbert in 1839 (Glauert 1950a)</td>
<td>Gray in Grey (1841: 401) and Thomas (1888: 225).</td>
</tr>
<tr>
<td>Mongup</td>
<td>One specimen collected 1866</td>
<td>Krefft (1867). This cannot now be found in the collection of the Australian Museum, Sydney (S. Ingleby, pers. comm. 1999)</td>
</tr>
<tr>
<td>Near Hastings (c. 20 km northeast of Wandering)</td>
<td>1898</td>
<td>In a letter written to the Director of WAM on 13.1.1898 from Wandering, John Tunney noted that I “expect to camp between here and Beverly for a week or so as I hear there are a lot of Rabbit Bandicoots about a place called Hastings”. See also Table 1.</td>
</tr>
<tr>
<td>Watheroo</td>
<td>1904 to 1906, details unknown</td>
<td>Museum specimen. Shortridge 1910: 833. I have been unable to trace further details.</td>
</tr>
<tr>
<td>Morawa area</td>
<td>–</td>
<td>Glauert (1950b) stated that the town of Morawa (gazetted 1913) was named after an Aboriginal word for the 'Dalgyte'. Goldsmith (1961: 10) repeated this but also provided an alternative derivation.</td>
</tr>
<tr>
<td>Grass Valley</td>
<td>1918</td>
<td>A. Gale (79 yrs in 1983) noted that he last saw a Dalgyte there 65 years ago (CALM file 015178F3807). A neighbour was fond of eating them. One animal observed to snap an onion in half with one bite.</td>
</tr>
<tr>
<td>Corrigin area</td>
<td>1923</td>
<td>L. Ainsworth with a black and white photograph of a Dalgyte (CALM file 015178F3807). The reverse side has the following caption: The last dalgyte I saw alive, caught in a rabbit trap at Corrigin. It’s back fur was blue and not grey...It was infested with hundreds of soft-bodied parasites about the size of a flea'.</td>
</tr>
<tr>
<td>Rabbit proof fence near Needilup</td>
<td>1920s to 1981</td>
<td>Elinor Pocock (b. 1920) recalled seeing a Dalgyte captured (unharmed) in 1923.</td>
</tr>
<tr>
<td>Benjaberring near Wyalakchem</td>
<td>1925</td>
<td>Tom Ball (b. 1919) recalled capturing one when trapping rabbits.</td>
</tr>
<tr>
<td>36 km west of Pinjelly, along York-Williams Rd</td>
<td>1920s to 1938</td>
<td>Alf Marshall (b. 1911) last saw the Dalgyte there c. 1925, soon after the Fox arrived.</td>
</tr>
<tr>
<td>Woogenilup</td>
<td>1902 to c. 1925</td>
<td>W.G. Pearce reported in 1963 (CALM file 015178F3807) that in 1902–3 old Dalgyte burrows were present though no animals were seen. In 1909 a few were sighted and the species remained until Foxes arrived. One animal observed dead [undated], killed by Fox. His grandson informed me that the area referred to is near Pearce Rd, c. 15 km from Mt Barker.</td>
</tr>
<tr>
<td>Watheroo</td>
<td>1928</td>
<td>Nicol Croot (b. 1912) came to Western Australia in 1928 and spent c. 3 months at Watheroo. Dalgytes were captured there when he was trapping rabbits.</td>
</tr>
<tr>
<td>c. 10 km southwest of Wongan Hills, near Lake Ninan</td>
<td>Late 1920s to 1939</td>
<td>Marjory McNeill (b. 1923) recalled one in c. 1928.</td>
</tr>
<tr>
<td>Woodamiling</td>
<td>1910s and 1920s</td>
<td>Ray Garston (b. 1931) stated that his father (b. 1897) mentioned their occurrence in 1928.</td>
</tr>
<tr>
<td>Locality</td>
<td>Years of Observation</td>
<td>Notes</td>
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</tr>
<tr>
<td>Morawa</td>
<td>1920s to present</td>
<td>John and Joyce White (b. 1923, 1927) observed Dalgyte burrows in heavier soils on their farm near Morawa, and John’s father had reported seeing a dead Dalgyte before 1920. Dalgytes were also reported to have occurred but only very locally in 1928-1929. It appears that the Dalgyte was a very rare species around Morawa, Merkanooka, Canna and Gutha, as Nicol Croot (b. 1912), Frank Lanagan (b. 1912), Patricia Yewers (b. 1916), Dick Sasse (b. 1920), Jim Stokes (b. 1924), Ken Tilley (b. 1924), Ken Granville (b. 1925), Brian Knight (b. 1927), Harvey Broad (b. 1929), Peter Collins (b. 1929) and Ron Baxter (b. 1931) had not seen it there.</td>
</tr>
<tr>
<td>South Caroling</td>
<td>Late 1920s to present</td>
<td>Henry Hall (b. 1920) last saw the Dalgyte in 1929. His father, who settled in the district in 1903, had informed him that Dalgytes were common then. Fox first recorded 1929.</td>
</tr>
<tr>
<td>c. 18 km east of Pingelly</td>
<td>Early 1920s to 1928, and then after 1942</td>
<td>Gil Gardner (b. 1918) last sighted Dalgytes on farmland (captured in Rabbit traps) in c. 1928 1929. Fox arrived c. 1923–1924.</td>
</tr>
<tr>
<td>Dryandra</td>
<td>1920s to present</td>
<td>Arthur Hunter (b. 1920) last saw Dalgytes there and in uncleared country between Dryandra and Narrogin in 1928–1929.</td>
</tr>
<tr>
<td>Culbin Siding</td>
<td>Before 1929</td>
<td>George Cowcher (b. 1929) did not know of the Dalgyte but recalled that his father had spoken of its occurrence on this farm before 1929.</td>
</tr>
<tr>
<td>East Woogenilup, c. 30 km from Mt Barker</td>
<td>Late 1920s to present</td>
<td>Jim Hunt (b. 1921) occasionally caught Dalgytes in rabbit traps. Not common. Last observed there c. 1929.</td>
</tr>
<tr>
<td>Near Mortlock River c. 7 km south of Northam</td>
<td>1920s</td>
<td>Jenkins (1974). See Appendix 1.</td>
</tr>
<tr>
<td>Norrine Hill (between Wandering and Hotham River)</td>
<td>1920s and 1930s</td>
<td>Kate White (b. 1912) remembered an isolated colony of the Dalgyte in Wandoo woodland on a farm on the southern foot of Norrine Hill. She last saw this species there in the late 1920s and blamed its disappearance on the Fox. She noted that the Dalgyte was not as common there as the Boodie.</td>
</tr>
<tr>
<td>Near Lake Grace</td>
<td>?1920s</td>
<td>Seen by Snow Gibbs when about 14 years old (CALM file 01517853807).</td>
</tr>
<tr>
<td>Marsh Rd, c. 7 km north of Qualeup</td>
<td>1912 to early 1920s</td>
<td>George Marsh (b. 1922) recalled his father (Edward, b. 1888), who settled there in c. 1912, speaking of the occurrence of the Dalgyte there. Fox arrived 1932–3.</td>
</tr>
<tr>
<td>c. 20 km east of Broomehill</td>
<td>1920s</td>
<td>Eric Fletcher (b. 1912) recalled that Dalgytes and their burrows were common in the area, especially in the sandy soils associated with patches of sheoak. He attributed their disappearance to cultivation and Fox predation.</td>
</tr>
<tr>
<td>Pallinup River near Gnowangerup</td>
<td>Early 1920s</td>
<td>‘Dalgite’ warrens recorded near river (Mouritz 1986)</td>
</tr>
<tr>
<td>Pallinup River near Gnowangerup</td>
<td>Early 1920s</td>
<td>Rex Herbert (b. 1926) recalled that his father spoke of the occurrence of Dalgytes on his farm there.</td>
</tr>
<tr>
<td>20 km north of Ongerup</td>
<td>1910s and 1920s</td>
<td>Susanne Dennings stated that her father mentioned Dalgytes as present on his farm (established 1912).</td>
</tr>
</tbody>
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Table 2 (cont.)

<table>
<thead>
<tr>
<th>Locality</th>
<th>Years of Observation</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>c. 10 km north of Kwolyin</td>
<td>1920s</td>
<td>Phil Stone (b. 1932) informed me that his father (b. 1904) spoke of Dalgytes on the farm where his father had lived c. 1923-c. 1940.</td>
</tr>
<tr>
<td>Quaalup and Marningerup Spring</td>
<td>1920s and ‘even later’</td>
<td>Chapman (1995: 92).</td>
</tr>
<tr>
<td>c. 6 km east of Woogenilup</td>
<td>1920 to 1938</td>
<td>Ted Ferry (b. 1914) last saw the Dalgyte there in 1930. They were not common and their burrows were in sandy soil within c. 500 m of the Kalgan River. They disappeared c. 5 years before the Fox arrived.</td>
</tr>
<tr>
<td>Henley Brook, near the corner of Gnangara and West Swan Roads</td>
<td>1925 to present</td>
<td>Frank Edgecumbe (b. 1908) saw Dalgytes occasionally up to 1930 in Jarrah/Banksia country (sandy soil). He linked their disappearance to Fox predation.</td>
</tr>
<tr>
<td>c. 8 km northwest of Tammin</td>
<td>1920s to 1950</td>
<td>Jim Masters (b. 1917). Last seen 1931.</td>
</tr>
<tr>
<td>c. 20 km northeast of Dalwallinu</td>
<td>Late 1920s to present</td>
<td>Milton McNeill (b. 1923). Never very plentiful on farmland (which still has much uncleared vegetation). Last seen 1933, with tracks for several years afterwards. Disappearance attributed to fumigation of burrows, Fox predation, and distribution of poison baits for rabbit control.</td>
</tr>
<tr>
<td>6 km west of Cuballing</td>
<td>1920s to 1930s, then 1946 onwards</td>
<td>Norm Candy (b. 1914) noted Dalgytes as scarce (e.g. 10–15 Boodies to each Dalgyte). Last observed c. 1933. As a child he trapped both species for pocket money, with each worth c. 1 shilling per skin. Fox arrived c. 1930.</td>
</tr>
<tr>
<td>c. 16 km WNW of Katanning (Kojonup Location 444)</td>
<td>1927 to present</td>
<td>Neville Beeck (b. 1920) noted presence of 3–4 burrows in an area of c. 20 ha. Last observed c. 1933. Fox arrived c. 1928.</td>
</tr>
<tr>
<td>c. 9 km ESE of Hyden</td>
<td>1930s</td>
<td>Dick Lane (b. 1930) reported that his father caught a Dalgyte in a rabbit trap in c. 1934; Dick told me that he has never seen one. He blamed their disappearance on the Fox, which began to establish in the district in c. 1935.</td>
</tr>
<tr>
<td>Tarin Rock and Kukerin</td>
<td>1920s to 1934</td>
<td>Douglas (1980). Athol Douglas (b. 1915) stated that Dalgytes were very common. He once observed one eating a snake.</td>
</tr>
<tr>
<td>‘Yaralla’, Woogenilup (c. 23 km from Mt Barker)</td>
<td>Late 1920s to present</td>
<td>Colin Adams (b. 1922) recalled that Dalgytes were ‘not uncommon’ in mallee plain country. They were occasionally captured in rabbit traps. Last seen there c. 1934.</td>
</tr>
<tr>
<td>Cowalla and Guilderton, Moore River</td>
<td>Early 1920s to 1977</td>
<td>“Dalgytes...were common along the [Moore] River” near Cowalla pastoral station, some 20 km southeast of Lancelin, as well as near Guilderton (de Burgh 1976: 65, 187). Bill de Burgh (b. 1912) told me that he occasionally caught Dalgytes in Dingo traps at Cowalla. Burrows were numerous to the extent that when cantering a horse through the bush, one had to watch for Dalgyte burrows. Disappearance (late 1920s to early 1930s) linked to Fox (arrived c. 1925) and poisoning of rabbits with phosphorus baits. Noted that Dalgytes in</td>
</tr>
</tbody>
</table>
digging burrows pile up excavated soil into a heap, unlike rabbits. Udell (1979: 327) recorded the occurrence of the 'Dalgyte' in the Gingin area before the 1920s, noting that they lived in "huge colonies on sandplains" and were "smelly animals". The reference to odour is clearly to the Dalgyte, as mature males emit a strong odour when stressed (C. Sims, personal communication 1999).

Fred Boase (b. 1921) recalled that Dalgytes were occasionally caught on his farm in rabbit traps. Last seen c. 1935.

Main (1967: 87). Captured in rabbit traps "less than thirty years ago". Possibly still present in the 1960s ("recently observed tracks in the wodjil"). Barbara Main (b. 1929) advised me that she last saw a Dalgyte in c. 1935, when her brothers had captured one while trapping rabbits.


<table>
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<tr>
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<tbody>
<tr>
<td>About halfway between Goonallling and Dowerin, 2 km south of highway</td>
<td>1920s to present</td>
<td>Fred Boase (b. 1921) recalled that Dalgytes were occasionally caught on his farm in rabbit traps. Last seen c. 1935.</td>
</tr>
<tr>
<td>c. 14 km north of Bungalla, on Bungalla-Yorkrakine Rd ['Fairfields' farm]</td>
<td>1930s</td>
<td></td>
</tr>
<tr>
<td>c. 12 km north of Katanning (on road to Wagin); also more generally in the Katanning district. Glenelg Rd, c. 8 km north of Isongerup Peak</td>
<td>1880s to 1940s</td>
<td></td>
</tr>
<tr>
<td>c. 15 km southwest of Mullewa (Devil's Ck)</td>
<td>Early 1930s to 1939, 1943 to 1970</td>
<td>Basil Moir (b. 1922) recalled that Dalgytes lived along Woolaganup Creek but were not common. Last seen c. 1935. Fox arrived c. 1929.</td>
</tr>
<tr>
<td>10 km north of Wickepin</td>
<td>Early 1930s to present</td>
<td>Jim O'Brien (b. 1927) saw one Dalgyte in a remnant Salmon Gum woodland on his father's farm in 1936.</td>
</tr>
<tr>
<td>c. 4 km northeast of Highbury</td>
<td>Mid 1920s onwards</td>
<td>Bill Butler (b. 1924) last observed the Dalgyte in 1936. There were 20–30 burrows on his farm, close to rocks. Fox not common until early 1930s.</td>
</tr>
<tr>
<td>c. 10 km southwest of Highbury</td>
<td>Mid 1920s onwards</td>
<td>Gwon Warren (b. 1917) last observed the Dalgyte c. 1936. Fox arrived c. 1927. She attributed their extinction to the Fox, habitat loss, and phosphorus poison baits laid for rabbits.</td>
</tr>
<tr>
<td>Near Minniging, 15 km northwest of Narrogin (Bradford Road)</td>
<td>From 1920s</td>
<td>Dos Vickers (b. 1919) last observed the Dalgyte in the 1930s. It was a common animal. Fox arrived c. 1928.</td>
</tr>
<tr>
<td>Mokine, between Spencers Brook and Clackline</td>
<td>1944 to 1945</td>
<td>Dawson Bradford (b. 1915) and Bill Bradford (b. 1918) remembered Dalgytes from the 1920s until c. 1939 (when Dawson went to war) and c. 1942 respectively. Dawson Bradford recalled that they occurred in sandy high country (c. 6 animals in a warren) and did not live in the same warrens as the Boodie Bettongia lesueur. He believed that both species became locally extinct after a feline enteritis outbreak during World War II, and not as a result of Fox predation. Bill Bradford thought that both species declined after poison baits for rabbits were distributed and following the establishment in c. 1928–1930 of the Fox.</td>
</tr>
<tr>
<td>c. 6 km northeast of Merredin</td>
<td>1920s to 1962</td>
<td>Harry Butler (b. 1930) recalled catching Dalgytes in rabbit traps on his way to high school in Northam.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M.B. Mills (CALM file 015178F3807). Margaret Mills (b. 1916) recalls seeing Dalgytes in Jam</td>
</tr>
<tr>
<td>Locality</td>
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</tr>
<tr>
<td>Duck Rd, c. 5 km northeast of Mt Barker</td>
<td>Late 1920s to 1947</td>
<td>Jerry Enright (b. 1923) informed me that Dalgytes were common in this area (Jarrah/Marri forest) and lived in warrens near an apple orchard. 'A few dozen' were trapped in the 1930s and their skins sold, a valuable source of pocket money. Noted as difficult to skin. Last recorded in the early 1940s. Disappearance attributed to arrival of Rabbit (late 1930s) and Fox (1937).</td>
</tr>
<tr>
<td>Farm adjacent to northern boundary of Tutanning NR</td>
<td>1946 to 1969</td>
<td>Judy Dhu (b. 1924) recalled that she never caught Dalgytes in Rabbit traps, unlike Boodies. Both species last recorded there in c. 1958. Neither species was recorded on the nature reserve in the period 1967-1970 (Sampson 1971).</td>
</tr>
<tr>
<td>8 miles (c. 13 km) east of Billericay Siding</td>
<td>1956 or 1957</td>
<td>R. Loveridge of Narembeen reported one Dalgyte seen (Fisheries Dept WA Bulletin for Honorary Wardens 1957 4(1-4): 20).</td>
</tr>
<tr>
<td>Mount Churchman reserve, north of Beacon</td>
<td>1959</td>
<td>Dalgytes sighted by C.A. Gardner in November 1959 (CALM file 03959F3807).</td>
</tr>
<tr>
<td>Mokine, between Spencers Brook and Clackline</td>
<td>1920s to present</td>
<td>Tom Wilding (b. 1919) recollected the occurrence of a colony on his farm in the 1950s. The colony was destroyed by bulldozers when a major powerline to Kalgoorlie was installed. The persistence of this colony may have been assisted by the introduction of 1080-dosed grain in 1954 to poison rabbits. Fox numbers may have been kept low by secondary poisoning resulting from eating poisoned rabbits (Christensen 1980).</td>
</tr>
<tr>
<td>Near Cramphorne Peak</td>
<td>c. 1958; 1962</td>
<td>Sighted by T.J. Hooper of Muntadgin (CALM file 015178F3807).</td>
</tr>
<tr>
<td>Wongan-Ballidu Shire</td>
<td>Not disclosed</td>
<td>'Dalgyte' noted as a 'mere name' [i.e. locally extinct] (Ackland 1965: 104).</td>
</tr>
<tr>
<td>Goomalling (Avon Location 2753)</td>
<td>c. 1967</td>
<td>One seen by J.A. Schell's mother. His father remembered this species as present in the 1920s.</td>
</tr>
<tr>
<td>Jitarning</td>
<td>1967</td>
<td>Two animals seen by A. Cook and a Mr Nash during clearing operations. Both knew this species as children (CALM file 015178F3807).</td>
</tr>
<tr>
<td>c. 27 km south of Cranbrook on Salt River Rd at Middle Springs waterhole</td>
<td>1973</td>
<td>D. Gillam sighted (during the day) two Dalgytes, noting their long ears and crested tail (CALM file 015178F3807). He had lived in the Cranbrook area as a boy and noted that Dalgytes were common there 40 years before. Dalgyte found in the district, no details provided (Antonio-Crake 1974: 6).</td>
</tr>
</tbody>
</table>
The Bilby *Macrotis lagotis* in south-western Australia

<table>
<thead>
<tr>
<th>Locality</th>
<th>Years of Observation</th>
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</tr>
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<tbody>
<tr>
<td>Toodyay district</td>
<td>Not disclosed</td>
<td>Erickson (1974: 2).</td>
</tr>
<tr>
<td>12 km northwest of Lake Grace</td>
<td>1978</td>
<td>A. Marshall and J. Stevens saw animals at late dusk and early morning on farmland. One was chased on foot. Described as like a rabbit, with long, tufted tail (CALM file 015178F3807).</td>
</tr>
<tr>
<td>Maringarup Rd, North Gairdner</td>
<td>1964 to 1978</td>
<td>F. Plapp made several sightings of Dalgytes in a paddock opposite the Bremer River. Five burrows noted in sandy hillside (CALM file 015178F3807).</td>
</tr>
<tr>
<td>South Stirling: Area</td>
<td>1960s to 1980s</td>
<td>Terry Marden (b. 1934), a bulldozer contractor who cleared parts of the South Stirling area by dragging a log or chains behind a tractor, reported seeing Dalgytes regularly while clearing. Last seen in the early 1980s. He also reported that burrows matching those seen in the South Stirling area were numerous on his father's farm on Yellanup Rd, between Woodlands and Rogers Rds. No Dalgytes were seen on this farm, however.</td>
</tr>
<tr>
<td>Mukinbudin Shire</td>
<td>Not disclosed</td>
<td>Dalgyte 'fairly common in these parts' (Maddock 1987: 20).</td>
</tr>
</tbody>
</table>

Additional information to that reported in Kitchener and Vicker (1981) for three key specimens from Clackline (M687), Chidlow (M980) and Culham (M1391). M687 was donated in February 1925 by E.W. Memberg of the State School at Clackline. It is a reasonable supposition that this specimen was collected by a pupil and brought to school for exhibition and that its provenance is near Clackline. M980 was donated in February 1928 by a Mr Garland of Buckland near Northam. There is no reason to doubt that the specimen was collected close to Chidlow. M1391 was evidently collected by a Mr Sam F. Howie at Culham via Toodyay and transmitted by E.W. Beard to WAM, where it was accessed in April 1931.

Two specimens (M1399, M1749) labelled 'Bridgetown' were respectively collected by E.T. Moyes in 1931 and H.S. Moyes in 1933. Initial enquiries about the collection locality by CALM Science officer A. Annels revealed that Harry Moyes (b. 1921) lived on a farm ('Prestbury') comprising Nelson Location 2313, c. 8 km southwest of Bridgetown on Mokerdillup Road. In January 1997 and November 1998 I interviewed Harry Moyes, who advised that his father (Ernest) took up this Location in 1921. At that time little clearing of forest had taken place. Dalgytes were not uncommon in the Bridgetown district in the 1920s, though the species was very rare on his farm, which is why he sent the specimen to the museum. He collected specimen M1749 on 19.5.33 when he was trapping rabbits in a burrow near the orchard on the farm. He told me that Dalgytes disappeared soon after he saw the first Fox *Vulpes vulpes* in 1936. In his 1933 letter to WAM, Harry Moyes wrote 'If I catch any more [Dalgytes] I will send them to you' (File A199/74/21).

The museum specimen (M452) from Mokerdillup (donated by Fredric Foster in 1921) is acceptable. Harry Moyes advised me that Foster lived on a farm ('Mokerdillup') on Nelson Location 1248, at the head of Pink Eye Gully, a tributary of Mokerdillup Brook. The specimen was apparently collected on the farm, as Foster wrote on 21.1.21 that it had been "picked up dead here" (WAM letter archives, File A199/74/11). Foster also noted that the animal had "evidently only been dead a few hours" and observed "a few small tooth marks, probably a cats, on the throat". Its stomach "seemed to contain a great many grass seeds". The occurrence of the Bilby in the area was clearly very local, as Foster wrote "...people who have been in these parts for 50 years & more admit to having seen nothing like it before".

Observational Records

These records, all from within the RFA area of south-western Australia, are listed chronologically by year of last observation.

1. The record published by Spencer (1966) of 'dalgitcs' in the first years of settlement (1860s) near Darkan refers to observations made by
W.J. Gibbs of Boolading Homestead. Tom Perry (personal communication to K. Morris 1994) also observed the Dalgyte from near Darkan. This record is considered too vague to be mapped and cannot now be clarified as Tom Perry is deceased.

2. Near Bannister. John Tunney wrote to the Director of WAM on 9.8.1900 from ‘The Williams’ that he “will try & get the P Lagotis you require between here and Bannister”. On 15.8.1900, at Bannister, he wrote “I am camping here [i.e. Bannister] for a few days to try & get the P lagotis as Mr Pollard tells me there are some about”. On 22.8.1900 he wrote that he “had traps set [at Bannister] every night for Lagotis I caught 5 but only got a female this morning she has two young ones in Pouch”. These quotations are from the original letters, held by WAM.

3. Buckingham. Les Carroll (b. 1926) reported that his father lived at Buckingham from 1910 and had mentioned the occurrence of the Dalgyte there.

4. Near the Warren River. Bill Young (b. 1915) remembered seeing them once, in 1921, c. 200 m west of Wordimup Pool (Wilgarup River) and recalled their burrows as present in the area. This area is in Quillben forest block. He first saw the Fox there in 1928.

5. Camballup, Kent River, c. 3 km north along the river from Muir Highway. George Higgins (b. 1914) last saw the Dalgyte there in 1921 in jarrah forest on his father’s farm.

6. Pinjarrah-Boddington Road, c. 2 km west of Hotham River crossing. Arthur Batt (b. 1917) saw one Dalgyte there in c. 1922-3 and recalled that this species was not common in the Marradong area. The few burrows observed each occurred close to the foot of a tree. The Fox arrived c. 1935.

7. c. 8 km north of Kulikup, near Balgarup Rd. Jim Torrie (b. 1921) told me that his father, who settled there in 1908, had spoken of the occurrence there of the Dalgyte before the mid 1920s. Fox arrived 1933.

8. Farm at Doust Road c. 19 km east of Bridgetown. Hilda Green (b. 1901) recalled that her father showed her in the 1920s a Dalgyte, which had been killed when the horse he was riding put a hoof into its burrow. Burrows were numerous on the farm. Hilda Green recalled that her husband first observed the Fox there in the early 1930s.

9. Sussex Loc. 2149 near Margaret River (town), adjacent to Bramley forest block. Bill Nilsson (b. 1914) arrived there as part of the Group Settlement Scheme in 1922 with his parents. He recalled seeing a few Dalgytes in 1926. Fox arrived c. 1930.

10. Near Coolingoort, Salt Valley Road, northwest of Bakers Hill. Walter Chitty caught one Dalgyte in c. 1927 in a trap on a farm (Avon Location 1681). Walter Chitty stated that the Dalgyte was rare and that the Fox arrived in the district in c. 1932.

11. Mokine, between Marradong and Quindanning, (Williams Location 82 and adjacent locations). Charles Fawcett (b. 1912) recalled the presence of the Dalgyte c. 1925–7. He linked its disappearance with the arrival of the Fox in c. 1930.

12. 100 m north of Nelson Location 1640 (near Walcott forest block). Ken Smith (b. 1912), a retired farmer and Dingo trapper, recorded a large warren “about 3 acres in area” dug up by the burrowing activities of Dalgytes. He used to catch the occasional Dalgyte in a Dingo trap. Ken Smith’s father (T.E. Smith) selected this land in 1897 and acquired nearby Locations 7881, 1636 and 1638. Ken Smith stated categorically that the Dalgyte did not occur on these other Locations. It preferred depressions in open Jarrah forest that were not waterlogged but contained yellow sands, presumably to facilitate burrowing. The species was consequently patchy in its distribution. He last saw Dalgytes there in 1928, two years after the Fox arrived.

13. Halfway between Nelson Location 1636 and Corbalup Swamp (Kingston and Corbal forest blocks). Ken Smith also reported that he caught one Dalgyte in a Dingo trap in about 1929. There was only a single burrow nearby.

14. Farm c. 3 km west of Boyup Brook on Bridgetown Road. Josie Outridge (b. 1907) recalled that her mother captured a Dalgyte on the farm in the late 1920s and skinned and stuffed it. Burrows were present on the farm. The Fox was first observed here in the early 1930s.

15. Farm on Campbell Road near Matta Matta Brook, c. 5 km east of Bridgetown. Brenda Trigwell (b. 1914) saw a Dalgyte in 1929 on her father’s farm and stated that they were common at that time.

16. Farm 36 km west of Beverley, along the Dale River. Geoff Lodge (b. 1933) reported that his father (Verne, b. 1898) had spoken to him of the occurrence there of the Dalgyte between the wars. Geoff never saw one there.

17. Near Duranillin. WAM in 1999 acquired a rug made from c. 16 Dalgyte skins (catalogued as Object No. H99.475). The rug was made in the 1920s from Dalgytes trapped on farmland near Duranillin (A. Haebich, personal communication 1999).

18. Mt Anderson, close to the town of Toodyay. Walter Chitty (b. 1919) recalled that a Dalgyte was caught at this locality in c. 1930.

19. Farm c. 8 km east of Boyup Brook on the
Blackwood River. Janet Purse (b. 1917) recalled the presence of burrows and that a Dalgyte was trapped there in c. 1930.

20. Deeside, Hay Location 6. Andrew Muir (b. 1917) stated that Dalgytes were not common in this area and were last seen c. 1931. The Fox arrived in 1934. He attributed the disappearance of the Dalgyte, Boodie and Woylie and decline of possum species (all early 1930s) to disease. His brother, Jim Muir (b. 1920), had not observed the Dalgyte, perhaps suggestive of an earlier decline.


22. South side of Lake Towerrinning. Lowden Cochrane (b. 1924, personal communication to John Schinzig 1999) saw a Dalgyte there in c. 1931–32.

23. Sussex Loc. 2292, Osmington, next to the Hay Location 36, near Hay River c. 5 km east of Plantagenet Location 4192, c. 4 km east of Forest Hill. George Elverd (b. 1912) recalled the presence of Dalgytes and their warrens in 1932 on farmland. His mother tanned Dalgyte skins for domestic clothing. Fox first recorded c. 1931.

25. Plantagenet Location 4192, c. 4 km east of Kent River near South Coast Highway. Len Turner (b. 1917), who lived on this farm from 1924 to 1938, recalled the occurrence of animals fitting the description of the Dalgyte. They were not common and were seen in the late 1920s and early 1930s. This farm originally carried Karri, Jarrah, Yarri and Banksia vegetation.


27. Near the southeast corner of Julimar forest (Trig forest block). Sam Cook (b. 1916) caught a Dalgyte in c. 1930 when trapping rabbits on farmland (Avon Location 5870), in Marri / Wandoo / Powderbark woodland. He first observed the Fox in c. 1928. His brother Harry Cook (b. 1923) observed a few Dalgytes close to the homestead on Avon Location 5870 in c. 1935.

28. Near Hotham River, c. 5 km north of Boddington. Jim Farmer (b. 1918) recalled that Dalgytes were plentiful in the district. On his farm they occurred in sandy hollows near the river. Last observed c. 1935. Fox first recorded in the early 1930s.

29. Near the Warren River at Nelson Loc. 320, adjacent to Quininup forest block and c. 3 km west of Warren hall site. Cliff Mottram (b. 1920) recalled seeing Dalgytes in this area until c. 1935. They were not common. The Fox arrived in this locality in c. 1930.

30. Ranford, c. 1 km northeast of Boddington. Vera Farmer (b. 1925) remembered capturing a Dalgyte in a rabbit trap and releasing it unharmed (1937).

31. Brancaster farm, c. 10 km south of Dinninup. Harold Whistler (b. 1907) caught a Dalgyte in a rabbit trap set in a burrow in sandy soil in c. 1937.

32. Farm c. 1 km north of Bridgetown. Stan Doust (b. 1922) first saw Dalgytes there in c. 1932 and blamed their disappearance in the late 1930s on the arrival of the Fox.

33. Bannister (Williams Location 43 and adjoining locations). Horace Pollard (1899–1972) had told his son Alec (b. 1937), whom I interviewed, of the occurrence of the Dalgyte on this farm. The species disappeared soon after the arrival of the Fox.

34. Haddleton farm (Wellington Location 1300) c. 1.5 km northwest of Trigwell Bridge. Richard Trigwell (b. 1912) stated that Dalgytes were last seen there in the 1930s and were uncommon.

35. Farm at Moodiarrup (Williams Loc. 221). Michael Cusack (b. 1939), whom I interviewed, informed me that his father settled there in 1929 and had spoken of the occurrence of the Dalgyte there. Michael Cusack also has in his possession a typed document of a conversation with a Mrs Trigwell recalling her life at Moodiarrup in the 1890s. This document mentions the presence of ‘Dalgyts’.

36. Swampy areas between Warren Bridge and Dombakup Brook (near Warren River and Barker/Callcup Road intersection), and near Lake Jasper. Fred Brockman (b. 1925) informed me that his father had spoken to him, while mustering cattle in these areas in the 1930s/40s, of the occurrence of Dalgytes in these localities. His father considered them as plentiful and remarked that they had disappeared suddenly, attributing this to a virus followed by the arrival of the Fox in c. 1930–1.

37. Wellington Loc. 1804, Quindanning-Harvey Road, adjacent to Williams River (c. 4 km southwest of Mt Saddleback). Basil Fletcher (b. 1936) remembered the Dalgyte on farmland and last saw it in 1947.

38. Sussex Location 921 on the Blackwood River (between Darradup and Sollya forest blocks). Vic Roberts (b. 1920), whom I interviewed in June 1997, recalled one animal and one burrow in sandy soil in forest that had been ringbarked
in 1903 and was densely vegetated in 1947, when the observation was made. Older settlers had reported Dalgytes even farther to the south west. Vic Roberts informed me that Dalgytes occurred also along St John Brook. The local Aboriginal name was Cundin. He first saw the Fox in this area in 1929.

39. Hay Location 342, Crosby/Quindinup Road, c. 4 km north of Frankland River/Muir Highway crossing. Robert Crosby (b. 1953) recalled that his mother had mentioned the occurrence of the Dalgyte on this farm up until the early 1950s.

40. Near Wooroloo. W.H. Butler (b. 1930) noted that a farmer had caught a Dalgyte in a trap in 1955 (CALM file 015178F3807). Harry Butler informed me that this was north of Burma Rd.

41. Werribee (Methodist Boys’ Home). W.H. Butler noted that a Dalgyte was seen there in 1956 during clearing (CALM file 015178F3807). This locality is c. 6 km east of Wooroloo (Harry Butler, personal communication 1999).

42. Avon River near Wooroloo. W.H. Butler reported Dalgytes there in 1956 and 1957 (CALM file 015178F3807). Harry Butler informed me that they were caught in rabbit traps set at Moondyne Spring.

43. 43 miles from Perth on Dale Rd (i.e. c. 69 km from Perth on Brookton Highway, which places the locality between Watershed and Yarra Rds). In March 1958 H.W. Norris and R. Abbey saw a Dalgyte at 10 pm hopping along the side of the road (CALM file 015178F3807; see also Fisheries Dept WA Bulletin for Honorary Wardens 1959 5(1): 11–12). The description provided is accurate. This was the first time in 25 years that H. Norris had seen a Dalgyte.

44. Along Perup River, between Yerraminrup River and Boyup Brook-Cranbrook Road, especially Nelson Loc. 2889. Ashley Giblett (b. 1919) stated that when he moved there in 1939 Dalgytes were very plentiful along, and up to 100 m from, the eastern bank of the Perup River. Last seen c. 1975. Fox arrived c. 1933.

**Negative Records**

The term ‘negative record’ in the context of the Bilby refers to the absence of reliable observations from localities where observations were made of other conspicuous mammals. Such records need to be treated cautiously, however, as absence of evidence can not necessarily be equated with evidence of absence (e.g. Ride 1970: 20). The best that can be achieved is to document negative records and examine whether they form a pattern that complements the known distribution based on records and observations.

1. Caves between Boodjidup and Karridale, Leeuwin-Naturaliste National Park. No remains of Bilbies have been retrieved from these caves (Lundelius 1957; Merrilees 1968a, b; Archer and Baynes 1973; Baynes et al. 1976; Balme et al. 1978; Porter 1979). Woodward (1914) listed *Macrotis lagotis* as a component of the fossil mammal fauna from Mammoth Cave, and this was repeated by Glaubert (1926, 1948) and Lundelius (1960). However, Merrilees (1968a, b) could find no specimens to support this identification and concluded that it was incorrect. Particularly significant to this point is the fact that *M. lagotis* was not one of the inland species (including *Perameles bougainville*, *Betongia lesuur*, probably *Lagorchestes hirsutus*, *Petrogale lateralis*, *Notomys sp.*, *Pseudomys albocinereus* and *P. occidentalis*) that invaded the southern Leeuwin-Naturaliste region during the drier times of the last glacial but disappeared from the area before or during the Holocene (Baynes et al. 1976; Balme et al. 1978).

2. Swan Coastal Plain. The occurrence of the Bilby on the Swan Coastal Plain south of Millendon is not supported by the surface fossil record or observations of George Moore and John Gilbert in the 1830s and 1840s. There is a substantial literature on the mammal faunas from the caves of the northern Swan Coastal Plain between Wanneroo and Dongara (Lundelius 1957, 1960; Merrilees 1968b; Archer 1972, 1974a, b; Baynes 1982). Among all the specimens identified, there is just one record (of a single jaw) of *M. lagotis*, from Wedge’s Cave, northeast of Lancelin (Lundelius 1960, personal communication 2000). The material originated from more than 2 m depth in the deposit and, on the basis of the radiocarbon date reported by Lundelius (1960), is probably several thousand years old.

John Gilbert made no mention of Bilbies at Perth, Mt Eliza, banks of the Canning River south of Perth, Fremantle, Pinjarra, Drakesbrook, Harvey, Australind or Vasse River (see Fisher 1992). See also Gilbert’s comments about distribution cited in Appendix 1.

George Moore lived at Millendon (Swan Locations 5a and 6) from 1830 to 1852 and recorded observations about conspicuous fauna in his letters from 1830 to 1841 (Moore 1884). He did not mention the occurrence of the Dalgyte on or near his farm. Living off the land was an urgent necessity for most settlers in the 1830s; if Bilbies were present near Perth there should be records in letters, but none have been found (Durack 1976; Statham 1981).

Evidence against the occurrence of the Bilby in the Perth metropolitan area is that most other medium-sized mammal species that occur or occurred within the area are well represented in the WAM mammal collection by pre-1934 specimens and/or catalogued records. Examples include *Chuditch Dasypus geoffroii*, *Numbat Myrmecobius fasciatus*, *Quenda Isoodon obesulus* and *Koomal*.
The Bilby *Macrotis lagotis* in south-western Australia

*Trichosurus vulpecula.*

The presence of the Bilby in the Gingin-Lancelin area, in and adjacent to the northeast sector of the Swan Coastal Plain, is believed to represent a specialized incursion only. Gingin lies in the middle of an area of uplifted Mesozoic sediments that form a block between the Hill River and Darling Scarp. These substrates differ from the highly leached sands characteristic of the Swan Coastal Plain. The presence of relatively friable Mesozoic sediments in the catchment of Gingin Brook (e.g. Molecap Greensand) and along part of the Moore River (Seddon 1972) may therefore explain the presence of Bilbies along the Moore River, if the outwash fans from the scarps associated with it are large enough not to be inundated by the Quaternary sediments blowing inland across the coastal plain.

The record supposedly from Kelmcott, noted in a letter by J.T. Tunney on 15.8.1900 (and quoted by Kitchener et al. 1978: 68 as “Mr. Pollard tells me there are some (M. lagotis) about the pool near Kelmcott”) is considered to be a misreading of what Tunney actually wrote (see the correct quotation under number 2 above).

The proposal of Glauert (1933: 17) that the Bilby attempted to establish itself near Perth where formerly it was entirely absent (presumably alluding to specimen M703 and M787) is considered implausible. The Upper Swan specimen (M703) is supported by an observational record near Henley Brook (see Table 2). M787 was donated by a Mr Hillard in July 1926, having been “found run over near Swan Brewery” (WAM mammal catalogue), “killed by motorcar” (specimen label), Mounts Bay Road, Perth. Kitchener and Vicker (1981: 157) listed this specimen as from “Perth G.F.O. (approx)”.

An undated specimen from Port Leschenault [Bunbury] presented to the Natural History Museum in London [BM(NH)] by a W.E. Bates (Thomas 1888: 225) and reference to ‘dalgerts’ in a book (Buckton 1840: 96) ostensibly about the Bunbury region are suggestive of the occurrence of the Bilby on the southern Swan Coastal Plain. I remain unconvincing. Buckton (1840) appears to have compiled accounts from the settled parts of W.A. The reference to the Bilby is in a paragraph discussing the food of Aborigines without allusion to any particular locality and appears to have been paraphrased from Ogle (1839: 63). I concur with Whittell’s (1954a) judgment that references to fauna in Buckton (1840) have been “obviously compiled without any knowledge of the facts”.

H.W. Bunbury, the first European to travel overland between Pinjarra and Vasse, does not mention the Dalgyte (Bunbury and Morrell 1930), nor do early residents of Bunbury and Australind (see Johnston 1962; Bolton et al. 1991, 1992). The BM(NH) specimen may have come from the Margaret River area, from inland after Bunbury was linked to Kojonup by road in 1840, or from a pet animal. Bilbies are attractive animals and were on occasion kept as pets (Reid 1837; Millett 1872: 169; Wood Jones 1924: 164; Le Souef and Burrell 1926: 300; Jenkins 1974: 170–1; notes about WAM specimen M1377 in Table 1). Animals in South Australia have been kept successfully in captivity for nearly 3 years (Aslin 1982).

My conclusion from the above records, taken together, is that Bilbies did not occur on the typical sandy soils of the Swan Coastal Plain at the time of European settlement. As noted by Baynes (1979: 203), the large burrows of Bilbies would probably collapse if dug into pure sand.

3. Margaret River. Shortridge (1910) did not collect or record the Bilby from Burnside or Ellenbrook. He readily obtained specimens of other species now rare or extinct there, namely *Macropus geoffroii*, *Pseudocheirus occidentalis* and *Dasyurus geoffroii*, and Bilbies elsewhere (see Table 1), and so is unlikely to have overlooked the Bilby if it had occurred at these localities.

4. Albany. No local Aboriginal name was recorded by Nind (1831). Gilbert (1843a, b) did not list it (see also Whittell 1954b, Fisher 1992). Shortridge (1910) did not record it from King River or Big Grove. George Masters’ specimen from the vicinity of King George Sound (Krefft 1867; Glauert 1950a: 126) is surely referable to Mongup, not Albany. This is the case with several bird species collected by him (Abbott 1999).

5. Wellstead district. Not listed by Leighton (1996). Not observed by Doug Moir (b. 1931) who has lived at Cape Riche since 1931. In addition, his father (Neil, b. 1898) had never spoken of the occurrence of Dalgytes at Cape Riche (Doug Moir, personal communication 1999). Not present at Warriup (Bill Hassell, b. 1927, personal communication 1999).

Residents of south-western Australia aged 70 years or more are an additional, though less scientific, source of negative records. Given that the last specimen was collected in 1935, I reasoned that a child of at least 5 years and living on a farm on which Bilbies were present would be unlikely to forget an observation of this morphologically extraordinary animal. All interviewees (Table 3) had an impressive familiarity with most of the medium-sized and large species of mammal present in the southwest in the 1920s and 1930s. Dick Perry, the most senior of the interviewees, was from 1917 a forester and traversed “hundreds of miles” of forest on foot and horseback. Many of these
traverses were before Rabbits established in the forest, when any excavations by Bilbies would have been conspicuous. Dick Perry marked the areas that he knew well on maps supplied by me in May 1997. Moreover, Dick Perry is a keen naturalist and in neither his published papers (Perry 1971, 1973) nor his interview did he mention the occurrence of the Dalgyte in the forest known to him.

Modelling the Original Distribution of the Bilby in south-western Australia

Combining the acceptable museum and observational records of the Bilby with the mapped vegetation types indicates (Figures 1, 2) that the Bilby had an extensive distribution in the southwest at the time of European settlement.

Observational records completed much of the inferred distribution in the northern forests, based on the Chidlow (M980), Clackline (M687) and Culham (M1391) specimens. The modelled distribution indicates that the Bilby could have occurred extensively in the Julimar forest and in the northern jarrah forest as far west as Moondyne, Sawyers, Helena, Beraking, Dale, Brady, Leona, Cooke, Geddes, Boonerring, Duncan, Wells, Hedges, Bombala, George, Hakea, Bell, Chat, Bednall, Nalyerin, Trees, Palmer, Fleays, Centaur and Goonac forest blocks^1. Specimens from near Bridgetown (M1399, M1749, M452) generated an extensive inferred distribution north to Arcadia, Yabberup and Noggerup forest blocks, very nearly linking with Goonac forest block already mentioned. The mismatch between State Forest (forest blocks) and the original eastern extent of forest is evident from comparing Figures 1 and 2, and shows that much of this area has been converted to agricultural purposes. The inferred distribution extends west to Ryall and Mullalyup forest blocks, and then south to Nelson and Carter forest blocks.

The two observational records near Walcott forest block and in Kingston and Corbal forest blocks generated an inferred distribution southeast of Bridgetown and east of Manjimup to Keninup, Moopinup and Talling forest blocks. The observational records east of Bridgetown, around Boyup Brook, near Moodiarrup, and near Forest Hill generated an extensive, though patchy, inferred distribution on land now almost completely cleared for agriculture. The remaining southern observational records generated inferred distributions near Margaret River, along the Blackwood River and tributaries west of Nannup, along the Scott coastal plain, and along parts of the Warren River, and between Kent River and Denmark.

DISCUSSION

The hypothesized original distribution of the Bilby in south-western Australia developed in this paper, using vegetation data, differs from one predicted on the basis of climatic variables (Southgate 1990). The latter showed the Bilby not to have occurred so extensively in the southern or eastern jarrah forests but to have occurred on the coast near Albany and Denmark.

How Reliable are the Bilby Records?

Museum Specimens

All of the WAM specimens were collected in the period 1900-1935, an era before and just after the Fox arrived in south-western Australia. However, typical of most species (Ride 1968), the suite of Bilby specimens collected is unrepresentative. This is for several reasons: resources were scarce; WAM had a policy at the time of not collecting specimens (A. Douglas, personal communication 1999); and the regional decline and local extinction of the Bilby and other medium-sized mammal species were not foreseen. Nonetheless, WAM curator L. Glauert actively solicited the donation of specimens of small marsupials from the public, including school teachers and rabbit trappers. Specimens forwarded to the museum by rail were carried free and the Trustees were prepared to consider payment for rare species (various letters dated 1928, filed at WAM in A199/74/15 & 21).

Conflicts in the Oral Data

There are gratifyingly few disagreements in the oral information collected, with most of the negative records complementing the inferred distribution of the Bilby based on positive (museum and observational) records. Particularly heartening is the strong concordance of oral information and museum records in the wheatbelt (see Figure 1, Tables 1 and 2).

The inferred distribution indicates that suitable habitat for the Bilby occurs in Sawyers, Helena and Beraking forest blocks east and southeast of Mundaring. Dick Perry, however, did not know of the occurrence of Dalgytes in this forest. When in the area he was involved in planting pines at Beraking. The observations by Vic Roberts on the Blackwood River are from an extensive area of the Donnybrook sinklands traversed by Dick Perry, who was not aware of the occurrence of Dalgytes there (see also Perry 1971). The observations by Bill Nilsson and Leonard Burton near Margaret River conflict with Shortridge’s lack of mention of the

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1 State Forest consists of 418 management units called forest blocks, each of c. 5 000 ha. Because the forest is sparsely settled, the most convenient method of referring to records within State Forest is by nominating forest blocks. A map (scale 1:650 000) of the forest showing the names of all forest blocks is available from Information Management Branch, CAIM, Como.
Bilby at two localities close by, and several negative records (Table 2). These minor discrepancies may indicate that occurrences of the Bilby near Mundaring, the lower Blackwood River, and Margaret River were very local. It is possible that Bilbies occurred along the lower Blackwood River only where suitable substrate exists along the river valley but not on either side.

The inferred distribution indicates the presence of suitable habitat for the Bilby near Brookhampton, Newlands, Kirup, Balingup and Greenbushes. As its former occurrence in this area has not been confirmed, this remains a significant discrepancy. On 7.9.1999 the Donnybrook-Bridgetown Mail published a letter from me seeking further information from readers about the occurrence of Dalgytes in this area. This elicited one response (A. Foan, b. 1929, Wellington Location 17, who did not know the term Dalgyte), thus reinforcing my belief (based on evidence of seven interviewees cited in Table 3) that the Bilby did not occur between Donnybrook and Greenbushes.

Because I have only one observation of the Dalgyte on the south coast west of Denmark, its geographic range limit there has been indicated tentatively in Figure 1 by a dashed line.

Biogeographic Significance

The penetration of the Bilby from inland south-western Australia into the Bridgetown area and then farther downstream along the Blackwood River is of considerable biogeographic interest. It is not, however, unique as other inland species show a similar coastal or subcoastal south-western termination to their range (Shortridge 1910; Perry 1971; Abbott 1999 and unpublished). These species are the Woylie Bettongia penicillata (to Margaret River), Boodie B. lesueur (to Donnybrook Sunklands), Malleefowl Leipoa ocellata (to Leeuwin-Naturaliste ridge, Lake Muir, karri forest, Scott River plain), White-browed babbler Pomatoschistus superciliosus (Vasse River and karri forest) and Crested shrike-tit Falcunculus frontatus (Swan Coastal Plain, Leeuwin-Naturaliste ridge and karri forest).

Possible Causes of the Decline and Presumed Extinction of the Bilby in South-western Australia

The museum records and observational data presented in this paper demonstrate that the Bilby up to 1935 was reported widely from south-western Australia and was clearly not an uncommon animal in most of this region. After that year, there are fewer dated reports (all observations): 1936, 1937, 1939, 1942, 1945, 1946, 1947, 1955, 1956, 1957, 1958, 1959, 1962, 1967, 1970, 1973 and 1978 (Figure 3). Many factors prima facie appear to have contributed to the decline and apparent extinction of the Bilby in south-western Australia. Indeed, Jenkins (1974) noted that no entirely satisfactory explanation had yet been presented for the population crash in the 1930s. The following analysis seeks to place in historical context the 15 factors usually invoked to explain declines of mammal species in south-western Australia (Shortridge 1910; Le Soeuf 1923; Baynes 1979; Kitchener et al. 1980; Burbidge and McKenzie 1989; my interviewees) and to determine which if any of the factors have primacy.

![Figure 3](image-url)
Drought

The occurrence of years with low rainfall in the Mediterranean climate of south-western Australia is frequent and natural (e.g. 1837–41, 1849–50, 1865–6, 1870s, 1881, 1894, 1897, 1903, 1911, 1914, 1919 (Haddleton 1952; Leake 1962; Erickson 1971; Garden 1979; Prince 1984; Meteorological Bureau data for Perth 1880 – 1998). Although it is unconvincing to link the decline of the Bilby solely to drought, it is relevant that most of the period from 1935 to 1940 experienced below average annual rainfall. Mammal populations in Australia do decrease during periods of low rainfall (e.g. Shortridge 1910; Leake 1962; Tunbridge 1991; Baker et al. 1993; Rose 1995; Short et al. 1997; Braithwaite and Muller 1997). Drought has been linked to the decline of Bilby populations in the Kellerberrin area by 1899 (Leake 1962) and in parts of the Northern Territory by 1965 and subsequently (Johnson and Southgate 1990).

Changed Fire Regimes

Changes in the pattern of fires resulting from European occupation, resulting in large areas of vegetation kept at the early stages of pyric succession, may have been a principal cause of the onset of mammal declines in the Western Australian wheatbelt (Kitchener et al. 1980). The critical factor is to what extent species depended on late successional patches for food and shelter. Large scale homogeneity is unlikely to be relevant to the Bilby, which persisted throughout the era of clearing burns, e.g. near Gnowangerup in 1912 (Bignell 1977) and the wheatbelt in 1900–10 when the area cleared increased from 30 000 ha to 235 000 ha (Glynn 1975). Prescribed burning in forests was introduced progressively from 1954 to 1961 (Abbott and Loneragan 1986) and thus post-dates the regional decline and apparent extinction of the Bilby.

Aboriginal Predation

Aborigines are known to have hunted the Bilby for food (see Appendix 1; also Troughton 1965: 70). I have found no record that they hunted Bilbies in south-western Australia for their tail tips (for decorative purposes), as was the case in central Australia (see Johnson and Southgate 1990). Aboriginal populations in south-western Australia declined precipitately after 1860 following the spread of European diseases (Green 1984). This may have led to an increased Dalgyte population in the following 30–40 years. Aboriginal predation as a factor in the decline of the Bilby can thus be discounted.

Pastoralism

Shortridge (1910: 818) linked the decline of several mammalian species to the introduction of sheep, particularly in arid parts of Western Australia, before the arrival of rabbits. Sheep divert or export nutrients formerly available to native mammals (Burbridge and McKenzie 1989). Although sheep were depastured throughout much of south-western Australia in the period 1850–1900 (Jarvis 1979), the Bilby showed no sign of decline then as evidenced by its widespread occurrence in the wheatbelt up to about 1930. Moreover, the Bilby’s shelter and food resources are mostly subterranean and there does not appear to be a direct link between damage to ground cover by sheep and the ecology of the Bilby.

Dingo Predation

Corbett (1995) proposed that the Dingo may have played as great, if not a greater, role in the decline and extinction of medium-sized mammals than other factors. The expansion of the pastoral industry in south-western Australia from the 1850s enabled the Dingo to increase in abundance and thus have a pronounced impact on smaller mammal species during periods of drought. Although the Dingo may be a contributing factor in certain areas, the weakness of this theory is that it can not explain why extinctions of mammal species also occurred in the deserts far from pastoral stations.

Relevant here are observations by Jim Masters (b. 1917), who farmed at North Tammin until 1950. He noted that Dingoes were still common there until 1930 and that Foxes did not become common until after 1930. Near Northam, the Dingo had been extirpated and Foxes were very common in the late 1920s. The Bilby was last seen at North Tammin and Northam in 1931 and c. 1928, respectively.

Feline Predation

The Cat Felis catus colonized south-western Australia with European settlement in 1826 and increased in distribution with the expansion of settlement, especially pastoralism (Abbott 2000). Cats initially commanded high prices because rodents and small native mammals infested dwellings and store rooms (Erickson 1974; Heal 1988). The Cat thus coexisted with the Bilby for 50–100 years. Furthermore, although adult Bilbies weigh 800–2500 g (Johnson 1995), which is well within the prey size of cats, cats prefer to eat animals of the size of a young rabbit, 200–300 g (Jones 1977; Coman 1991). It is unclear how capable the Bilby is in defending itself from attack, as some will bite readily and savagely (Wood Jones 1924; Troughton 1965; A. Gale and J. Schugg CALM file 015178F3807; N. Beeck personal communication 1999), whereas others are docile (Christensen and Liddelow 1992). Cat predation can be discounted (cf. Watts 1969).
The Bilby *Macrotis lagotis* in south-western Australia

**Trapping for the Fur Trade**

Following settlement, especially from 1885 to 1910 (Erickson 1974; Haebich 1988) and again during the 1930s Depression, the Koomal *Trichosurus vulpecula* was snared throughout the southwest for its pelt and was the basis of an important export industry. Although Bilby skins were sold (Jenkins 1974; Mouritz 1986; J. Enright personal communication 1999), this was not a commercially attractive activity because of the strong smell and difficulty in preparing skins (Jenkins 1974). This is in contrast to South Australia, where skins were collected in very large numbers (Wood Jones 1924). Trapping for the fur trade as a cause of Bilby decline can be discounted for south-western Australia.

**Disease**

There are anecdotal records of spectacular declines in native mammal species attributed to disease (e.g. Shortridge 1910; Grasby 1925; White 1952; Spencer 1966; Perry 1973; Erickson 1974; G. Gardner cited in How *et al.* 1987: 565; B. Hanekamp and A. Muir personal communication 1997, 1999). Shortridge in particular noted declines in otherwise little altered parts of the inland, except for the presence of sheep, horses, rats, mice, cats and dogs. It is now well established that marsupials are sensitive to toxoplasma, for which the cat is a vector, not the sheep or dog (Andrew Thompson, Veterinary and Biomedical Sciences, Murdoch University, personal communication 1999). It is also possible that fleas or ticks on introduced mammals (Roberts 1952) may have spread disease among native mammals. Ray Garstone (b. 1931) informed me that his father reported that Dalgytes were common in 1928 near Woodanilling town site. His father last saw them in 1936, noting that he found dead animals present. This event was attributed by his father to disease.

John Tunney in 1913 implied that Dalgytes were rare at Gracefield, south of Kojonup, as he noted “There are still a few left about this locality”. My study is suggestive of a more extensive decline between 1920 and 1935. Following settlement, especially from 1885 to 1910 (Erickson 1974; Haebich 1988) and again during the 1930s Depression, the Koomal *Trichosurus vulpecula* was snared throughout the southwest for its pelt and was the basis of an important export industry. Although Bilby skins were sold (Jenkins 1974; Mouritz 1986; J. Enright personal communication 1999), this was not a commercially attractive activity because of the strong smell and difficulty in preparing skins (Jenkins 1974). This is in contrast to South Australia, where skins were collected in very large numbers (Wood Jones 1924). Trapping for the fur trade as a cause of Bilby decline can be discounted for south-western Australia.

Clearing of *Vegetation for Agriculture*

Le Soeuf (1907: 404) attributed apparent extinction of Dalgytes to cultivation and ringbarking of trees on farms. Clearing of native vegetation on first class land [Salmon Gum, Gymlet, Morrell and Jam woodland] for cultivation was regarded by Douglas (1980; personal communication 1999) as relevant. However, Dalgytes could sometimes be found near Northam in cultivated paddocks in the late 1920s (Jenkins 1974) and their burrows were found near Kellerberrin often in cleared land (Leake 1962). L. Jenkins also noted two burrows in a garden at the foot of a fruit tree (Letter to L. Glaeurt 6.7.1927, held in WAM archives). N. Beeck (personal communication 1999) also reported that Dalgytes lived on cleared land near Katanning. Hobbs *et al.* (1993) implicated fragmentation of the original vegetation in the extinction of the Bilby in the WA wheatbelt. However, in many parts of the wheatbelt, clearing was not extensive until the 1960s (Muir 1976: 17, 20; Muir 1977a: 27; Muir 1977b: 14–15; Chapman 1978: 10–14; Chapman 1981: 11). The pattern of railway construction in the wheatbelt serves as an early indicator of when and where most clearing took place. The maps published by Glynn (1975) thus demonstrate extensive clearing in the western wheatbelt in the period 1909–18.

The area alienated for farmland or sown for grain actually declined throughout the 1930s (Burvill 1979: 43), as a consequence of a severe economic depression curtailing the marketability of agricultural produce. Yet, as is clear from Tables 1 and 3, there are few records of Dalgytes after 1935. Habitat removal and fragmentation through clearing for agricultural development, though it may cause local declines and extinctions, has not caused significant or widespread declines or extinctions of mammal species (Burbidge and McKenzie 1989). Watts (1969) also indicated that the decline and disappearance of the Bilby in New South Wales and South Australia (c. 1900) preceded extensive habitat alteration, so that this factor could not have been a prime cause. The most telling counter-evidence is the failure of the Bilby to persist in the Great Victoria Desert or several large areas of uncleared vegetation within or adjacent to cereal-growing areas, e.g. Stirling Range NP (116 000 ha), Lake Magenta Nature Reserve (108 000 ha), Lake King NR (40 000 ha), Dragon Rocks NR (32 000 ha), and Dryandra Woodland (formerly ‘State Forest’, 28 000 ha).

**Rabbit – Competition for Resources**

Rabbits colonized south-western Australia in the period 1905–25 (Long 1988). Hoy (1923) believed that Rabbits are “the worst of agents working toward the extinction of the native fauna”. Morton (1990) placed emphasis on the patchy distribution of nutrients in arid landscapes and proposed that native mammal species relied on patches of nutritious plant growth during droughts. These patches were postulated to have then been preferentially depleted by exotic grazers and browsers such as Rabbits. Hobbs *et al.* (1993) also...
Table 3  Negative records of the Bilby within or near the original extent of forest in south-western Australia. Listed chronologically by the year at which observations began.

<table>
<thead>
<tr>
<th>Name</th>
<th>Years of observation</th>
<th>Localities and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andrew Torrent (b. 1903)</td>
<td>1907 to 1923</td>
<td>Yoongarillup (c. 12 km east of Busselton). Fox first recorded 1922</td>
</tr>
<tr>
<td>Dick Perry (b. 1902)</td>
<td>From 1919</td>
<td>Near Gnangara, Mundaring, Hamel, Argyle, Margaret River east to Nannup, Pemberton to Walpole, Denmark</td>
</tr>
<tr>
<td>Charlie Tozer (b. 1913)</td>
<td>1920 to 1934</td>
<td>Eastbrook Group Settlement No. 8, near Pemberton</td>
</tr>
<tr>
<td>Louis Torrent (b. 1915)</td>
<td>1920 to 1939</td>
<td>Yoongarillup</td>
</tr>
<tr>
<td>Ernest West (b. 1916)</td>
<td>1922 to present</td>
<td>Cowaramup (Sussex Loc. 2943-4, 3851, 4004). Rabbit and Fox arrived c. 1932.</td>
</tr>
<tr>
<td>Philip Blond (b. 1916)</td>
<td>1923 to 1929</td>
<td>Cowaramup Group Settlement No. 20. Rabbit and Fox arrived in early 1930s</td>
</tr>
<tr>
<td>Les Court (b. 1913)</td>
<td>1923 to 1939</td>
<td>Five Mile Brook, near Pemberton</td>
</tr>
<tr>
<td>Dick Smith (b. 1917)</td>
<td>Early 1920s to 1934</td>
<td>Grimwade. Fox first recorded c. 1934.</td>
</tr>
<tr>
<td>Eileen Croxford (b. 1914)</td>
<td>1924 to 1929</td>
<td>Group settlement at Parryville, c. 18 km west of Denmark</td>
</tr>
<tr>
<td>George and Dorothy Brenton</td>
<td>1924 to 1945, 1945</td>
<td>Mt Shadforth area near Denmark</td>
</tr>
<tr>
<td>Dick Charteris (b. 1905)</td>
<td>From 1925</td>
<td>Near Wilga</td>
</tr>
<tr>
<td>Ted Ashton (b. 1914)</td>
<td>1920s to present</td>
<td>Margaret River (town and adjacent areas)</td>
</tr>
<tr>
<td>Fred Bannass (b. 1914)</td>
<td>From 1920s</td>
<td>Near Channybeareup (next to Big Brook forest block)</td>
</tr>
<tr>
<td>Frank Brockman (b. 1915)</td>
<td>1920s to 1936</td>
<td>Dudinyillup (Nelson Locations 6 &amp; 7). Fox arrived c. 1928-30</td>
</tr>
<tr>
<td>Wes Forrest (b. 1915)</td>
<td>1920s &amp; 1930s</td>
<td>Yallingup (to 1932), Balingup (1932-33)</td>
</tr>
<tr>
<td>Alf Simmonds (b. 1916)</td>
<td>1920s &amp; 1930s</td>
<td>Collie</td>
</tr>
<tr>
<td>Rob Brockman (b. 1917)</td>
<td>1920s to 1988</td>
<td>Dudinyillup (Nelson Locations 6 &amp; 7). Fox arrived c. mid 1920s</td>
</tr>
<tr>
<td>Les Cluett (b. 1917)</td>
<td>1920s to present</td>
<td>Near Porongurup Range (area bounded by Spring, Mt Barker-Porongurup and Chester Pass Rds). Fox arrived c. 1933-5. He knew of the Bilby’s occurrence in the Woonaillup area</td>
</tr>
<tr>
<td>George Treloar (b. 1917)</td>
<td>From 1920s</td>
<td>4-5 km southwest of Boyup Brook on Blackwood River</td>
</tr>
<tr>
<td>Vern Scott (b. 1918)</td>
<td>1920s to present</td>
<td>Tanjanerup (Nelson Location TAA 13)</td>
</tr>
<tr>
<td>Gordon Padman (b. 1918)</td>
<td>From 1920s</td>
<td>Near Brookhampton (Wellington Locations 235/81). Fox first recorded early 1930s</td>
</tr>
<tr>
<td>Clem Mitchell (b. 1918)</td>
<td>From 1920s</td>
<td>Near Newlands (Camfield, Wellington Location 727). Fox first noted c. 1932-33</td>
</tr>
<tr>
<td>Ted Mills (b. 1918)</td>
<td>1920s to 1942</td>
<td>Bowelling to 1942; thereafter at Collie. Fox first seen c. 1928</td>
</tr>
<tr>
<td>Roy Simmonds (b. 1919)</td>
<td>1920s &amp; 1930s</td>
<td>Collie</td>
</tr>
<tr>
<td>Lew Scott (b. 1920)</td>
<td>From 1920s</td>
<td>Near Storry and Strickland forest blocks; and near mouth of Donnelly River. Fox first recorded 1928-29</td>
</tr>
<tr>
<td>Arthur Dawson (b. 1921)</td>
<td>1920s &amp; 1930s</td>
<td>Near Northcliffe (to 1927), near Manjimup (to 1934), Dwellington (1934 onwards)</td>
</tr>
<tr>
<td>Arthur Watson (b. 1918)</td>
<td>Mid 1920s &amp; 1930s</td>
<td>Near Manjimup</td>
</tr>
<tr>
<td>Tom Ball (b. 1919)</td>
<td>1927 to present</td>
<td>Sawyers Valley and Mt Helena. Fox arrived 1930</td>
</tr>
<tr>
<td>Alf Tindale (b. 1919)</td>
<td>1928 to present</td>
<td>Kentdale</td>
</tr>
<tr>
<td>Dick Korn (b. 1910)</td>
<td>From 1929</td>
<td>Settled near Dwalganup (Nelson Location 3831)</td>
</tr>
<tr>
<td>Dave Stewart (b. 1921)</td>
<td>1929 to present</td>
<td>Walpole</td>
</tr>
<tr>
<td>Arthur Ashcroft (b. 1921)</td>
<td>From late 1920s</td>
<td>Near Dwellingtonup (His father knew of Bilbies in the Tambellup/Kojonup area c. 1914)</td>
</tr>
<tr>
<td>Ted Birmingham (b. 1921)</td>
<td>From late 1920s</td>
<td>Near Dwellingtonup (Murray Locations 94 &amp; 687)</td>
</tr>
<tr>
<td>Jack Dearle (b. 1922)</td>
<td>From late 1920s</td>
<td>Near Greenbushes, Balingup. Fox first observed at Balingup 1938</td>
</tr>
<tr>
<td>Roland Muir (b. 1922)</td>
<td>From late 1920s</td>
<td>West side of Lake Muir (until 1944)</td>
</tr>
<tr>
<td>Bob Pugh (b. 1922)</td>
<td>Late 1920s to 1979</td>
<td>Narrikup</td>
</tr>
<tr>
<td>Frank Souness (b. 1922)</td>
<td>From late 1920s</td>
<td>Merryup, c. 5 km west of Mt Barker. Fox arrived 1930</td>
</tr>
</tbody>
</table>
The Bilby *Macrotis lagotis* in south-western Australia

<table>
<thead>
<tr>
<th>Name</th>
<th>Years of observation</th>
<th>Localities and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cedar Armstrong (b. 1924)</td>
<td>Late 1920s to 1991</td>
<td>Carter Rd area near Margaret River (town), Sussex Loc. 1137, 464 and 933. Fox arrived early 1930s.</td>
</tr>
<tr>
<td>David Blythe (b. 1924)</td>
<td>From late 1920s</td>
<td>Near Nannup</td>
</tr>
<tr>
<td>Harry Mewett (b. 1924)</td>
<td>From late 1920s to present</td>
<td>Sussex Location 665, Quindalup</td>
</tr>
<tr>
<td>Keith West (b. 1925)</td>
<td>From late 1920s to 1972</td>
<td>Cowaramup (Sussex Location 1719)</td>
</tr>
<tr>
<td>Aub McEvoy (b. 1915)</td>
<td>From 1930</td>
<td>Dwellingup and Harvey</td>
</tr>
<tr>
<td>Wally Dunnett (b. 1928)</td>
<td>From 1931</td>
<td>Between Treen Brook and Fly Brook forest blocks</td>
</tr>
<tr>
<td>George Gardner (b. 1912)</td>
<td>From 1932</td>
<td>Near Northcliffe. He knew the Bilby from his childhood spent on a farm east of Pingelly, 1912-32 and stated that it started to decline in the 1920s following the widespread use of rabbit poison baits, before the Fox was first observed in 1928 near Pingelly</td>
</tr>
<tr>
<td>Basil Hanekamp (b. 1920)</td>
<td>From early 1930s</td>
<td>Middlesex; east side of Lake Muir (1948 onwards). Fox first seen at Middlesex in 1935. He noted that native mammals became scarce in the 1930s, and observed instances of them ‘travelling in circles’ which was attributed to disease</td>
</tr>
<tr>
<td>Lionel Scott (b. 1922)</td>
<td>From early 1930s</td>
<td>Near Storry and Strickland forest blocks; and near mouth of Donnelly River. Fox first observed c. 1934</td>
</tr>
<tr>
<td>Fred Brockman (b. 1925)</td>
<td>1930s to 1978</td>
<td>Dudindillyup (Nelson Locations 6 &amp; 7).</td>
</tr>
<tr>
<td>Ernie Young (b. 1925)</td>
<td>Early 1930s to 1946</td>
<td>Near Kin Kin forest block</td>
</tr>
<tr>
<td>Jack Studsor (b. 1925)</td>
<td>Early 1930s</td>
<td>Collie</td>
</tr>
<tr>
<td>Len Talbot (b. 1926)</td>
<td>From early 1930s</td>
<td>Near Nannup (Carlotta) until 1946</td>
</tr>
<tr>
<td>Les Carroll (b. 1926)</td>
<td>Early 1930s</td>
<td>Buckingham</td>
</tr>
<tr>
<td>Jimmy Shanahun (b. 1926)</td>
<td>Early 1930s to 1951</td>
<td>Woodburn area, southeast of Porongurup Range</td>
</tr>
<tr>
<td>Tom Warren (b. 1927)</td>
<td>From early 1930s</td>
<td>Dwellingup</td>
</tr>
<tr>
<td>Audie Kern (b. 1927)</td>
<td>From 1930</td>
<td>Pemberton</td>
</tr>
<tr>
<td>J.S. Whyte (b. 1927)</td>
<td>From early 1930s</td>
<td>Sussex Locations 1734 &amp; 1736, Wirring and Whyte Rds, between Bramley and Treeton forest blocks near Margaret River</td>
</tr>
<tr>
<td>Brian Mitchell (b. 1928)</td>
<td>From early 1930s</td>
<td>Near Newlands (farm, Wellington Location 2538)</td>
</tr>
<tr>
<td>Bevan French (b. 1929)</td>
<td>From early 1930s to present</td>
<td>Gidgegannup</td>
</tr>
<tr>
<td>Charlie Miles (b. 1932)</td>
<td>From early 1930s to present</td>
<td>Gidgegannup (Swan Location 149)</td>
</tr>
<tr>
<td>Laurie Butterly (b. 1915)</td>
<td>1934 to present</td>
<td>Sussex Loc. 963, Wildwood Rd near Yallingup. Fox arrived c. 1934–1935</td>
</tr>
<tr>
<td>Bruce Beggs (b. 1928)</td>
<td>1935 to 1939</td>
<td>East Kirup (Grimwade)</td>
</tr>
<tr>
<td>Fred Delandgraft (b. 1930)</td>
<td>From mid 1930s</td>
<td>Tonebridge</td>
</tr>
<tr>
<td>Walter Korn (b. 1907)</td>
<td>From 1938</td>
<td>24 km south of Boyup Brook</td>
</tr>
<tr>
<td>Neville Tichbon (b. 1928) &amp; Michael Tichbon (b. 1936)</td>
<td>From 1930s</td>
<td>Between Gwindinup and Argyle, adjacent to Preston River (Wellington Location 3217). Their father had told them that the first Fox was shot in the district in 1929.</td>
</tr>
<tr>
<td>Bill Tame (b.1924)</td>
<td>From 1940</td>
<td>Near Nannup</td>
</tr>
<tr>
<td>Frank Smith (b. 1910)</td>
<td>From 1947</td>
<td>c. 19 km west of Cranbrook. Before 1947 he lived at Bruce Rock and knew the Bilby there, where he last saw it in c. 1928</td>
</tr>
</tbody>
</table>

suggested that regeneration following fire was hindered by Rabbits. Being partly carnivorous, however, the Bilby should only have competed with Rabbits for tubers.

Usurpation of Bilby burrows by Rabbits was probably more relevant (Wood Jones 1924; Ratcliffe 1938; Rolls 1969; Watts 1969; J. Masters and N. Beeck personal communication 1999), although Bolam (1927) noted that Bilbies apparently “live in complete harmony” with Rabbits. In the early 1930s overproduction and declining wheat prices led to severe financial constraints (Bolton 1972: 189) and
facilitated the development of Rabbit plagues on farms in the 1930s (Tomlinson 1979). Perhaps it is only a coincidence that Rabbits are sparse to nearly absent in the northern and central deserts of Western Australia (King 1990), the only parts of Western Australia where the Bilby has persisted.

**Introduced Rodents**

The House mouse *Mus domesticus* probably became a valuable food resource for the Bilby (cf. Watts 1969). Because it was not a competitor for food, it was not instrumental in that way in the decline and apparent extinction of the Bilby in south-western Australia.

**Bycatch from Rabbit Trapping and Poisoning**

During the era of Rabbit plagues, poisoned grain and fruit were distributed in agricultural areas to control Rabbits (Crawford 1921; Hoy 1923; Haddleton 1952; Gooding 1956; Leake 1962; Troughton 1965; Udell 1979; Pustkuchen 1981; Ferrell 1992; G. Gardner and W. Bradford personal communication 1999). These baits reduced the abundance of parrots, native mammals and introduced mammals that ate this grain. This incidental mortality of non-target species is here termed bycatch. Being insectivorous and carnivorous (Longman 1922; Jenkins 1974; A. Douglas personal communication 1999), the Bilby ate poisoned grasshoppers, Rabbits, mice and birds (Haddleton 1952; Udell 1979; Pustkuchen 1981; A. Douglas, personal communication 1999). Haddleton (1952), G. Warren, and C. Fawcett (both personal communication 1999) linked the decline of the Dalgyte to poisoning. N. Candy (personal communication 1999) surmised that Dalgytes and Boodies died in their burrows after having eaten phosphorus bait, which is a slow acting poison; this may account for why this factor has generally been underestimated.

Bilbies were also killed through ripping and fumigation of Rabbit warrens on agricultural land (Glaeurt 1954; Serventy 1954; Jenkins 1974; Hobbs *et al.* 1993), or were killed or maimed in steel traps set for Rabbits (Shortridge 1910; Wood Jones 1924; Leake 1962; Jenkins 1974; N. Beeck, W. de Burgh, J. Masters, D. Vickers personal communication 1999). None of these Rabbit control measures, however, can explain the extinction of the Bilby in nature reserves and national parks and in the Great Victoria Desert, where these practices did not occur.

**Vulpine Predation**

The Fox colonized south-western Australia in the period 1920–30 (Long 1988). Bilbies declined in the southwest mostly within 10 years of the arrival of the Fox, with the last specimens collected in the area in 1935 (Kitchener and Vicker 1981, Australian Museum collection) and the last sighting in the 1980s (T. Marden, personal communication 1999). Many interviewees linked the disappearance of the Bilby with the Fox, as have Le Soeuf (1923), Bolam (1927), Serventy (1954), Finlayson (1961), Troughton (1965) and Watts (1969). Erickson (1971: 151) cited anecdotal evidence of “a sudden increase of foxes” in the period 1934–6, based on “an increase of 800% in sheep deaths” on a farm near Calingiri.

The failure of the Fox to become permanently established in the north of Western Australia (King and Smith 1985) may explain the persistence of the Bilby there and its apparent extinction elsewhere in the State (Friend 1990, Christensen and Liddelow 1992). Moreover, in the Warburton region and Gibson Desert the Fox is widespread and Bilby populations appear to be declining (Burbidge and Fuller 1979; Burbidge *et al.* 1988; Christensen and Liddelow 1992). In the Great Sandy Desert, Bilbies still persist (Youngson *et al.* 1981; McKenzie and Youngson 1983) and may be numerous (Burbidge and Pearson 1989), with Fox numbers decreasing at lower latitudes. In the southeast of WA Amy Crocker noted a decline in Bilby abundance at Ballardonia after 1917 following the arrival of the Fox (Richards and Short 1996). In 1929, Dingo trapper W.A. Wills collected Bilbies near Rawlinna, noting that “foxes were non existent or very rare” (A.J. Wills, personal communication 1999).

**Logging**

The Bilby occurred most extensively in forest with a codominant height <25 m (cf. Map 2 of Bradshaw *et al.* 1997; Figure 1 of this paper). Much of this forest remained unlogged until after 1960 (Heberle 1997), for the reason that it is commercially unattractive, as few trees have long boles. Even where it was logged earlier (1940–59), the low density of stumps (pers. obs.) indicates that the impact was not intensive. Furthermore, forest around Chidlow and Wooroloo, where the Dalgyte persisted to 1927–56, was logged in the period from 1880 to 1920 (appendix 5 of Heberle 1997). Much of the south-western geographic range limits of the Bilby lie almost completely east of the high quality jarrah forest (see map on p. 9 of Abbott and Loneragan 1986). For all these reasons, logging may be discounted as a relevant factor.

**Mining**

The earliest and probably most intensive impact of mining was east of Collie (Heberle 1997), where jarrah forest was logged for props for underground mine shafts in the period 1900–19. Mining for bauxite within the Bilby's geographical range was commenced by Worsley Alumina in 1984 at Mt Saddleback, well after the population crash of the 1930s. Gold mining began near Boddington in 1987 (Bartle and Slessar 1989). In all of these operations,
The Bilby *Macrotis lagotis* in south-western Australia

the actual extent of deforestation is relatively limited.

**Synthesis**

The above analysis has revealed that some factors are not relevant, others appear to have contributed indirectly, and several have directly influenced the decline and apparent extinction of the Bilby in south-western Australia. Moreover, some of these factors have cross-linkages. In order to clarify the role of this set of interacting factors, it is useful to recognize three categories.

In the context of this paper, pre-disposing factors to the extinction of the Bilby are those natural or pre-European variables that reduce, usually temporarily, population size: drought, aboriginal burning of vegetation, Dingo predation, and disease. Contributing factors are those that have reduced population sizes only since European settlement: clearing of native vegetation, spread of clearing burns to adjacent vegetation, crossing over of diseases from domesticated or feral animals, bycatch from rabbit control programs, and predation by Cats and Foxes. Primary factors are any of those listed with an overarching role in the process of extinction. In the case of the Bilby, all of the circumstantial evidence leads me to concur with the hypothesis proposed by Watts (1969), that the Fox is both the necessary and sufficient factor associated with regional declines.

This hypothesis can be tested by establishing when, in the range of the Bilby in southern Australia, the Fox arrived and the Bilby was last recorded or observed. Data for New South Wales, South Australia and Western Australia have been taken from Friend (1990), Leake (1962), Jenkins (1974), Ashby *et al.* (1990), Kemper (1990), Tunbridge (1991), Richards and Short (1996), and from this paper. The mean interval between the arrival of the Fox in a district and the last record there of the Bilby varied from 12 years in 1890 to 5 years in 1930 (Figure 4). As the Fox spread from southern Victoria, the Bilby disappeared sooner in southeast South Australia and New South Wales than in Western Australia and northwest South Australia, consistent with the hypothesis.

Drought is a significant pre-disposing factor in that it permits depletion of reduced populations of native species by Foxes and Cats (cf. Morton 1990). The late 1930s and early 1940s was a period of drought in south-western Australia. Fire, depending on its scale, intensity and frequency, temporarily modifies vegetation cover, an important factor in the presence of exotic predators. Sheep damage the ground cover and make it more open, assisting predation by Cats and Foxes. Pastoral areas also tend to have higher Fox numbers due to the presence of dead sheep and cattle on which Foxes can scavenge. Disease epidemics and clearing of native vegetation also reduce population sizes. Rabbits are important because they constitute key prey of Foxes (Catling 1988), allowing these predators to maintain high numbers and continue to prey on declining native species which might otherwise attain an equilibrium with the Foxes, albeit at lower population densities. Predation by

![Figure 4](image-url) Relationship between the year of arrival of the Fox in localities across southern Australia and the occurrence up to 1945 of the Bilby, now apparently extinct, in the same localities.
Foxes on native mammal species can be unremitting (Smith and Quin 1996). The accidental trapping of Bilbies by rabbiters and the poisoning of Bilbies during the era of the poison cart also reduced population sizes.

Implications for Conservation Management

Due consideration of all of the above issues leads me to formulate an hypothesis that: if the Fox had not established in south-western Australia, the Bilby would have persisted in national parks, nature reserves, the eastern portion of State Forest, and patches of remnant vegetation on agricultural land.

The Department of Conservation and Land Management is now poisoning Foxes over 3.5 M ha of native vegetation in south-western Australia, allowing those species that persisted locally to expand in distribution and abundance, and re-introducing populations of native mammals that have become locally extinct since the 1930s (Bailey 1996). There are proposals to introduce the Bilby to François Péron NP and Fitzgerald River NP, and re-introduce it to Dragon Rocks NR, Karroun Hill NR, Lake Magenta NR and Stirling Range NP (CALM 1999). Bilbies were re-introduced to Dryandra Woodland in May and June 2000. These actions will test the hypothesis stated above.

Translocations of the Bilby into the extensive area of State Forest marked on Figure 2 should also be considered, with initial priority given to the Perup forest. If these re-introductions succeed, the translocated animals should breed, disperse and eventually occupy all suitable habitat. Figure 2 predicts the extent of this distribution and thus the hypothesis proposed in this paper for the original distribution of the Bilby can be tested.

Further Research

A search of the compilation of accounts of early explorations published by Cross (1833) did not yield any records of Dalgytes. It was beyond the scope of this study to read the numerous exploration diaries held in Battye Library. These record observations made during the exploration of south-western Australia in the period 1829 to 1871 (listed by Jackson 1982: 187–195; mapped in Jarvis 1979). Diaries and letters of colonists may also produce additional records. One looks forward to the day when these items, together with colonial newspapers, are electronically scanned and the information contained in them is more readily accessible via searchable databases. Hopefully this paper will stimulate further historical research into circumscribing in more detail the southwest range limits of the Bilby.

Throughout this paper I have used the term ‘apparent extinction’ rather than ‘extinction’. The recent rediscovery of *Potorous gilbertii* at Two Peoples Bay (Sinclair et al. 1996) and the re-appearance, after only one year of Fox baiting, of species thought to have become ‘locally extinct’ at Lake Magenta NR (Morris et al. 1998) demand a more cautious approach to declaring species extinct. Although there was a population crash of Bilbies across regional south-western Australia, a few local populations appear to have persisted into the 1940s, 1950s, 1960s, 1970s and 1980s, almost at random. Why did these and not other populations persist? W.H. Butler (in Bennister 1969) did not locate Bilbies in the southwest localities investigated. Nor did Kitchener et al. (1980) locate Bilbies in 23 wheatbelt reserves studied in detail in the period 1971–6. Is there a slim possibility that a Bilby population still exists somewhere in south-western Australia?

The apparent persistence of the Bilby in south-western Australia for nearly 50 years after the last specimen was collected has an interesting implication for 11 other mammal species that were last collected in south-western Australia last century or early in the 1900s. These species, with their last year of collection and the collector, are: *Notomys longicaudatus, N. macrotis, Pseudomys fieldii, P. nanus, Rattus tunneyi and Chaeropus ecaudatus* (1840s, John Gilbert); *Potorous platyops* (1875, William Webb); *Lagorchestes hirsutus* (1896, John Tunney); *Perameles bougainville* and *Lagostrophus fasciatus* (1906, Guy Shortridge); and *Onychogalea lunata* (1908, John Tunney). In addition, *Bettongia lesueur* was last collected in south-western Australia in 1942 (by Norman Hall). Is it possible that some or all of these species remained undetected in south-western Australia for several decades after the last specimen was collected? If so, it would reinforce the concept, propounded above for the Bilby, that extinction can be a drawn out process to which a number of factors can contribute, and for which the primary factor may differ from species to species.

ACKNOWLEDGEMENTS

I thank: CALM officers A. Annels, R. Brazell, R. Fremlin, M. Graham, G. Liddelew, K. Low, N. Marchant, D. Mell, K. Morris, R. Round-Turner, L. Silvester, R. Smith, M. Stukely, K. Wallace, D. Ward, I. Wilson and T. Wood for suggesting contacts; the interviewees named in the text or listed in Tables 2 and 3 for their willingness and patience in answering my questions; J. Schinzig for his efforts in gathering three additional reports; A. Batt, S. Dennings, P. Leighton, D. Ride, E. Riley, A. Sanders, R. Stan-Bishop, C. Trotter, H. Turnbull and M. White for suggesting contacts; the residents of the southwest listed in Table 3 for providing important information about where the Bilby was not recorded; H. Smith for GIS-cartography; C. Fisher for the records from Gilbert’s MSS; A. Wills for information about W.A. Wills’ collecting for Taronga Zoo; N. Cooper and M. Triffitt and their
staff at WAM for allowing me access to specimens, catalogues and letter archives; the Australian Museum (per S. Ingleby) and Museum of Victoria (per J. Dixon) for allowing me to include, at no cost, specimen information from their mammal collections; D. Ride for providing details of specimens collected by Shortridge and others; M. Carleton, P. Horton, D. Lunde, and M. Rutzmoser for details of specimens in the National Museum of Natural History (Washington DC), South Australian Museum, American Museum of Natural History (New York), and Museum of Comparative Zoology (Cambridge MA), respectively; CALM librarian L. Wright for making available her ‘bibliography’ (bibliography of references to *Macrotis lagotis*); and A. Baynes, N. Burrows, P. Christensen and K. Morris for helpful criticism of the manuscript.

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*Manuscript received 11 May 1999; accepted 15 September 2000.*
Appendix 1

Chronological synopsis of information about the Bilby in southwestern Australia, based on observations in the period 1837–1935. The original spellings in the quoted documents have been retained.

<table>
<thead>
<tr>
<th>Information</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;...called by the natives Dolgict, and by the colonists the Rabbit...A friend of Mr. Gould's residing in Western Australia, states that these animals are found beyond the mountains of Swan River in the district of York. They feed upon large maggots and the roots of trees, and do considerable damage to the maize and potato crops by burrowing. A specimen kept by him in confinement became in a few days very docile, but was irritable, and resented the slightest affront or ill usage&quot;.</td>
<td>Reid, 1837</td>
</tr>
<tr>
<td>&quot;The animal called Dolgitch by the natives...burrows in the ground, and except in its tail, has a good deal the appearance of the European Rabbit&quot;.</td>
<td>Drummond, 1839 [Hooker, 1840: 362]</td>
</tr>
<tr>
<td>'dalgert'</td>
<td>Ogle, 1839: 63</td>
</tr>
<tr>
<td>'Dulgyte'</td>
<td>Armstrong, 1841</td>
</tr>
<tr>
<td>&quot;Some of the smaller animals, such as the dal-gyte...an animal about the size of a weasel, burrow in the earth; these the natives surprise when they are feeding, or dig them from their burrows&quot;.</td>
<td>Grey, 1841, vol. 2: 291</td>
</tr>
<tr>
<td>&quot;Dal-gyt...has no incisors or cutting teeth...opening of the pouch is from below instead of from above...burrows in the ground&quot;.</td>
<td>Moore, 1842 (see Moore, 1884: 23)</td>
</tr>
<tr>
<td>&quot;Dol-goitch...is a burrowing animal, living in pairs, and choosing spots where there is loose soil; its burrows are in general several feet in depth, and often of very great extent, and its powerful claws enable it to burrow with astonishing rapidity, which renders it anything but easy to capture; it often occurs that while the native is digging along its burrow, the animal becomes alarmed, and commences burrowing upwards from the extremity of its long burrow and thus makes its way out, generally unperceived by the man while employed digging. The Dolgotch in a state of nature seems to be almost exclusively an insect feeder, and one of its most favourite morsels apparently is the larva of a species of Cerambyx, found in the roots of the Jam-wood (Acacia) this grub too is eaten with great avidity by the Natives, who never fail to cut it out from an exposed root where the Dolgotch has been unsuccessful. The P[erameles] lagotis is tolerably abundant over the whole of the grass district of the interior where it is exclusively confined. The flesh is extremely delicate, and when boiled greatly resembles that of the common rabbit&quot;.</td>
<td>Gilbert, c. 1839–43 [Whittell, 1954b: 110]</td>
</tr>
<tr>
<td>&quot;Dal-goitch. Aborigines of the York districts'. This is followed by text similar to that quoted above from Whittell 1954b. The major difference is 'Although I have used the term Dalgyte, as it is in general use among the settlers the proper and correct word of the Natives is Dal-goitch&quot;.</td>
<td>Gilbert, 1843a</td>
</tr>
<tr>
<td>&quot;Dol-goitch. Aborigines generally&quot;. This is followed by text almost identical to that quoted above from Whittell 1954b. Note the following variation: &quot;is tolerably abundant over the whole extent of the sandy districts of the interior of Western Australia.&quot;</td>
<td>Gilbert, 1843b</td>
</tr>
<tr>
<td>&quot;There were several burrows like boudy holes, inhabited by animals whose tracks resembled those of the dalgite, in these plains, the earth around and thrown out...&quot; [August 1854, c. 80 km southeast of Mt Magnet]</td>
<td>Austin, 1856: 243</td>
</tr>
</tbody>
</table>

Gilbert's remarks about distribution paraphrased as "the grassy districts of the interior of the Swan River colony". | Gould, 1863 |
The Bilby *Macrotis lagotis* in south-western Australia

<table>
<thead>
<tr>
<th>Information</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;I have not forgotten the dinner which we had on our return, for it was an</td>
<td>Millett, 1872: 169</td>
</tr>
<tr>
<td>exceptional one on a bush animal called a <em>dolghite</em>... The <em>dolghite</em> proved,</td>
<td></td>
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<tr>
<td>as we had expected, so exceedingly like a rabbit when cooked that we could</td>
<td></td>
</tr>
<tr>
<td>detect no difference in taste...if the <em>dolghite</em> is cut up as for a fricasee</td>
<td></td>
</tr>
<tr>
<td>the slight difference in the shape of the two animals is unperceived, and</td>
<td></td>
</tr>
<tr>
<td>the flesh of both being white the deception is complete. The parallel,</td>
<td></td>
</tr>
<tr>
<td>however, does not extend to their disproportions, for the confidence of a</td>
<td></td>
</tr>
<tr>
<td><em>dolghite</em> is so difficult to obtain that my husband piqued himself not a</td>
<td></td>
</tr>
<tr>
<td>little in persuading one, that was given him as a pet, to be on terms of even</td>
<td></td>
</tr>
<tr>
<td>distant civility with us&quot; [1863-9, at York].</td>
<td></td>
</tr>
<tr>
<td>'dulgate' [1869, c. 30 km southwest of Mt Singleton. Two Aborigines</td>
<td>Forrest, 1875: 64</td>
</tr>
<tr>
<td>encountered with many animals carried in a net bag].</td>
<td></td>
</tr>
<tr>
<td>'dolgitte' [1870s, ?Dandaragin]</td>
<td>Lovat, 1914: 175</td>
</tr>
<tr>
<td>&quot;The dalyite runs on four legs like the rabbit, and is very light blue in</td>
<td>Haddleton, 1952: 98-99</td>
</tr>
<tr>
<td>colour with a long black tail with two inches of white on the end. His nose</td>
<td></td>
</tr>
<tr>
<td>and mouth are very much like a pig. His ears which are large are about the</td>
<td></td>
</tr>
<tr>
<td>size of a rabbit. His back feet are the same shape as the boody and his</td>
<td></td>
</tr>
<tr>
<td>forehands are long with four long sharp nails which are especially adapted</td>
<td></td>
</tr>
<tr>
<td>for digging. He is a grain eating animal but his chief food is bardies,</td>
<td></td>
</tr>
<tr>
<td>grubs or insects. He lived in a burrow in the ground but would only make</td>
<td></td>
</tr>
<tr>
<td>the one single burrow. The dalyite was the means of showing us where to</td>
<td></td>
</tr>
<tr>
<td>sink for water in the summer time. If you come to a burrow going almost</td>
<td></td>
</tr>
<tr>
<td>straight down on a sandy patch and there was moisture in the sand which</td>
<td></td>
</tr>
<tr>
<td>he had dug out of the burrow, you could bet your life he was going down</td>
<td></td>
</tr>
<tr>
<td>after water and many a good soak has been found through following the</td>
<td></td>
</tr>
<tr>
<td>dalyite. They were plentiful until the rabbit poison was laid out and I</td>
<td></td>
</tr>
<tr>
<td>have not seen one in this district since 1935, and he was a dead one.</td>
<td></td>
</tr>
<tr>
<td>Someone had run over and killed him&quot;.</td>
<td></td>
</tr>
<tr>
<td>&quot;...makes a larger and deeper burrow than <em>Betlongia</em> [lesiour]; the</td>
<td>Shortridge, 1910: 831-3</td>
</tr>
<tr>
<td>entrance also is almost perpendicular for about two feet and then takes a</td>
<td></td>
</tr>
<tr>
<td>side turn at right angles. Like a badger, it is difficult to dig for, and</td>
<td></td>
</tr>
<tr>
<td>will often burrow as fast as a man can dig...its tail during life has a</td>
<td></td>
</tr>
<tr>
<td>peculiar downward curl, although possessing no prehensile power. Nocturnal.</td>
<td></td>
</tr>
<tr>
<td>Not saltatorial, resembling a rabbit in its movements. Tail tipped with a</td>
<td></td>
</tr>
<tr>
<td>small sharp pointed horny spur rather like that of <em>Onychogale</em> ...widely</td>
<td></td>
</tr>
<tr>
<td>distributed throughout the South-West (except near the coast)...Most</td>
<td></td>
</tr>
<tr>
<td>plentiful in the inland districts of the South-West, rather frequently</td>
<td></td>
</tr>
<tr>
<td>caught in traps set for rabbits along the rabbit-proof fence...&quot;Dalgyte&quot;...</td>
<td></td>
</tr>
<tr>
<td>of natives [of southwestern Australia]”.</td>
<td></td>
</tr>
<tr>
<td>'Dalgoor'</td>
<td>Bolam, 1927: 27</td>
</tr>
<tr>
<td>&quot;The Dalgitte...a little larger and taller than the Boodie lived like it in</td>
<td>Leake, 1962: 50-1</td>
</tr>
<tr>
<td>burrows, though these were not so extensive as those made by that expert</td>
<td></td>
</tr>
<tr>
<td>digger. The Dalgitte also scoth out its burrows in similar types of soil,</td>
<td></td>
</tr>
<tr>
<td>but these were generally in open country, often on cleared land, and not</td>
<td></td>
</tr>
<tr>
<td>right up against rocks or under them. Aborigines say that it was almost</td>
<td></td>
</tr>
<tr>
<td>impossible for their women to dig out Dalgittes...because as soon as they</td>
<td></td>
</tr>
<tr>
<td>commenced to do so the fugitives did likewise, and burrowed deeper into</td>
<td></td>
</tr>
<tr>
<td>the ground. By about 1899 they had practically all gone from the Eastern</td>
<td></td>
</tr>
<tr>
<td>Wheatbelt, but in 1918 after three very wet years, they returned and</td>
<td></td>
</tr>
<tr>
<td>rapidly increased in numbers, and interfered with rabbit traps who</td>
<td></td>
</tr>
<tr>
<td>inadvertently caught many of them. At one period their population was</td>
<td></td>
</tr>
<tr>
<td>dense, and shortly afterwards these numbers decreased rapidly, and by</td>
<td></td>
</tr>
<tr>
<td>1929 they disappeared again, and have not returned. ...invariably twins</td>
<td></td>
</tr>
<tr>
<td>were found in a Dalgitte's pouch. Mainly carnivorous, they used to scratch</td>
<td></td>
</tr>
<tr>
<td>holes straight down to obtain the cream coloured bardies...found in the</td>
<td></td>
</tr>
<tr>
<td>roots...particularly those of the acacias, and this family of trees was</td>
<td></td>
</tr>
<tr>
<td>certainly the Dalgitte's favourite.”</td>
<td></td>
</tr>
</tbody>
</table>
“Despite its attractive colour and softness Dalgite fur was not popular with the trade, partly because the pelts were very tender and partly because of a persistent musty odour. In 1926 rabbits were still scarce in the Northam district and the first fox was exhibited...about a year later. By contrast the burrows of the Dalgite...were quite common in the bush and could sometimes be found in cultivated paddocks. In the early days of settlement the Dalgite was plentiful in what is now the Wheatbelt and no entirely satisfactory explanation has yet been presented for the population crash which occurred about 40 years ago [i.e. 1934]. Dalgites were quite common around Northam in 1926 and their scratchings in search of food could often be seen under jam trees and she-oaks. These scratchings could be distinguished easily from those of rabbits by their conical shape and depth. Although Dalgites fed mainly in the bush their scratchings and burrows were not uncommon in cultivated paddocks and in consequence most farmers regarded them as pests. The Dalgite burrow has but one opening and usually descends in a spiral, often to a depth of about five feet...I obtained a fine specimen which I kept for some time...It refused [to eat apples, grains of wheat, lucerne, lucerne roots, sods of green grass and in fact all the things which it was supposed to damage on the farm] but it did eat bread and milk...Mice and insects were relished, but earthworms were also acceptable, and when natural food was scarce, raw meat was a satisfactory substitute. About that time another pet Dalgite was being kept by L. Glauert...These two individuals were, as far as I am aware, the last South-west Dalgites to be kept in captivity...the final disappearance of the Dalgite was probably hastened by the spread of the rabbit...Undoubtedly wholesale clearing and perhaps the arrival of the fox played a part, but by the early 1930's rabbits were assuming plague proportions in many areas and massive control campaigns were enforced. These included not only property netting and poisoning with pollard and phosphorus (probably harmless to the Dalgite), but also burrow fumigation and warren ripping. Anything that looked like a rabbit burrow was treated and so the harmless Dalgite was a frequent, if unintended, victim.”

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<td>“Despite its attractive colour and softness Dalgite fur was not popular...</td>
<td>Jenkins, 1974</td>
</tr>
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<td>with the trade, partly because the pelts were very tender and partly...</td>
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</tr>
<tr>
<td>because of a persistent musty odour. In 1926 rabbits were still scarce...</td>
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<tr>
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</tbody>
</table>
Appendix 2

List of suspect observations of the Bilby in southwestern Australia, 1963–79. Information paraphrased from CALM file 015178F3807. Omitted are records of obviously misidentified animals or records based solely on supposed burrows of Dalgytes. Listed in chronological order.

<table>
<thead>
<tr>
<th>Locality and year</th>
<th>Observer</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mile from Prevelly Park, towards Margaret River (town), July 1963. Resighted in c. 1964 or 1965.</td>
<td>A. Pell saw an animal with long ears, long tail with white crest and ungainly locomotion at 5 pm in stunted peppermint scrub at the side of the road, part of a reserve.</td>
<td>Possible on geographical grounds. The animal was identified from the illustration in Troughton's book (Letter by Hon. Warden E.V. Teede in CALM file 015178F3807). Mr Pell was connected with the Prevelly Park Wildlife Sanctuary. Could the animal have been an escaped pet?</td>
</tr>
<tr>
<td>'Mosgiel', Tenterden, c. 1966</td>
<td>H. Wornum. Trapped on private property near a rabbit burrow and released.</td>
<td>Possible on geographical grounds. No description provided.</td>
</tr>
<tr>
<td>Farm at east Kondinin, c. 1967</td>
<td>L.S. Willey. One seen.</td>
<td>Possible on geographical grounds. No description provided.</td>
</tr>
<tr>
<td>Little Grove area, Albany, before March 1969</td>
<td>Const. Fitzgerald. Sighted on a number of occasions.</td>
<td>Improbable on geographical grounds. Identified from the illustration in Troughton’s book. Scats collected and scrapes and burrows were investigated by J.L. Bannister, Curator of Mammals, WAM, but were determined as being referable to the Rabbit. Could these sightings have been of an escaped pet Bilby?</td>
</tr>
<tr>
<td>Little Grove area, Albany, April and May 1969</td>
<td>J. White. c. 1 month after big fires. 9–10 p.m. Animal seen crossing road and described as having long pointed nose, long ears. Tail not seen</td>
<td>Improbable on geographical grounds.</td>
</tr>
<tr>
<td>Little Grove area, Albany, September 1969</td>
<td>C. Ostle (Inspector, Dept of Fisheries and Fauna). One seen crossing road, 8 a.m.</td>
<td>Improbable on geographical grounds. I interviewed Colin Ostle in 1999, but he could not recall this sighting. Could this sighting have been of an escaped pet Bilby? (Compare observations cited above for the same locality.)</td>
</tr>
<tr>
<td>c. 3 km northeast of Collie, Ewington area, 1971</td>
<td>I. Milroy, reporting observation of one animal by an unnamed neighbour.</td>
<td>Just possible on geographical grounds. No description provided. Secondhand report.</td>
</tr>
<tr>
<td>c. 9 km east of Busselton, Sussex Location 7, on Layman [?South] Rd. 1972</td>
<td>A. Selfe. One sighted. He reported that he had seen this species in recent years in the Mordialup area east of Manjimup and had caught dozens of them many years ago when they were plentiful in the southwest.</td>
<td>Improbable on geographical grounds. Possible on basis of experience of observer.</td>
</tr>
<tr>
<td>c. 19 km southeast of Borden (Kent Location 1233), 1973</td>
<td>R.G. Smith (reported)</td>
<td>Possible on geographical grounds. No description provided.</td>
</tr>
<tr>
<td>Buniche siding, 1979</td>
<td>R. Wilson, reported to J. Stevens. In burrow. Like a young rabbit, with a pig's nose and a long tail. Poor quality photograph on file.</td>
<td>Possible on geographical grounds. No description provided.</td>
</tr>
<tr>
<td>?Misidentified rabbits.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A review of Australian *Siphonicytara* Busk (Bryozoa: Cheilostomatida)

Philip E. Bock¹ and Patricia L. Cook²

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Abstract - Until recently, species of the deep-water ascophoran genus *Siphonicytara* have been recorded from only two areas, nearly 10,000 km apart. Three species were known from the East Indies and one from the southwest Indian Ocean. A hitherto unrecognized species is now known from the southern-most Philippine region, and six new species have recently been described from New Caledonia. A further new species from relatively shallow water, *S. occidentalis*, is described here from Western Australia. Examination of fossil specimens from the Tertiary of Victoria and South Australia has shown that specimens attributed to *Porina clypeata* Waters have a close relationship with *Siphonicytara*, and the species is referred here to this genus, as is *Mucronella airensis* Maplestone. Another Tertiary species with a similar distribution, *Eschara elevata* Waters not Tenison Woods, is assigned to *Siphonicytara irregularis* (Maplestone). The stratigraphic range for the family extends from the Late Eocene to Recent. *Eschara elevata* Tenison Woods *sensu stricto* is the type species of the genus *Tubilrabecularia* Bassler, and a discussion of the nature and status of this genus is included. A key to the species described is given.

INTRODUCTION

The genus *Siphonicytara* was introduced by Busk (1884) for *S. serrulata*, a deep-water species from the Celebes Islands (Sulawesi) from a depth of 1508 m. Two other Recent forms, *S. formosa* (from western Irian, 469 m), and *S. cylindrica*, (also from the Celebes, 1901 m), were later described by Harmer (1957). A further species, *S. symmetrca*, was introduced from very deep water from southeast of Madagascar in the Indian Ocean, from 4297 m depth, by David and Pouyet (1986). Recently Gordon and d’Hondt (1997) have described six new species from New Caledonia from a range of depths from 435 m to 1980 m. One of these species, *S. armata*, somewhat resembles another new form described here from Western Australia, *S. occidentalis*, which is not found from deep water. These colonies, like *S. formosa*, are anchored by rhizoids.

Gordon and d’Hondt (1997) noted, in passing, the similarities between *S. armata* and a species from the Sulu Archipelago in the southern Philippines region which was described by Canu and Bassler (1929: 154, plate 17, figure 4) as *Thalamoporella (?) insolita*. Their specimen consisted of one small cylindrical fragment from a depth of 619 m. Canu and Bassler (1929) were obviously very uncertain of the generic attribution of this species. They regarded the frontal shield as a cryptocyst with a distal opesia ('aperture'), and the raised septal ridges as the mural rims of zooids. The species is obviously referable to *Siphonicytara*, but understandably, was overlooked by Harmer (1957) in his discussion of the genus. *Siphonicytara insolita* is very similar to the Tertiary Australian species *S. clypeata*, described below, but has more robust branches and rounded avicularia.

Study of the numerous Tertiary specimens from Victoria and South Australia has shown that *Siphonicytara cylindrica* Harmer also has some similarities with *S. clypeata* (Waters). The genus is now known to have two further Tertiary Australian representatives, *S. irregularis* (Maplestone) and *S. airensis* (Maplestone). The increase in the number of known species belonging to *Siphonicytara* has necessitated a review of its characters and systematic affinities.

The systematic importance of the ascopore (which passes through the frontal shield calcification and opens into a sealed chamber with one flexible wall – the ascus), as opposed to the spiramen (which passes through peristomial calcification into an open space external to the operculum), has been discussed by Harmer (1957) and Cook (1973). The structure of some ascophorans in which the 'outer' calcified walls (interior walls) were almost all separated from the environment by coelomic tissue bounded by external cuticle, has been discussed by Cook and Chimonides (1981). Some of the species belonging to the family Didymosellidae which they
described (particularly those of the genus *Tubiporella* Levinsen), showed ontogenetic changes which resulted in the peristomial spiramen appearing to open in the centre of the zooid frontal shield. Similar changes occur in the family Adeonidae (Cook, 1973). *Siphonicytara* is of interest because, although it possesses a true ascopore, which often opens very closely to the proximal edge of the primary orifice, the ontogenetic changes involving elongation of the peristome, and the thickening of the calcification of the frontal shield, result in the ascopore appearing to open externally, in the centre, or even at the proximal end of the exposed frontal shield. In addition, as the external calcified walls of *Siphonicytara* are all interior walls, the family Siphonicytaridae provides an interesting analogue with *Tubiporella* and the Didymosellidae in general.

Astogenetic and ontogenetic changes of great complexity occur in some species of *Siphonicytara*. Of the Tertiary species, only one has been redescribed since its introduction during the last 90 years. The majority of these species has never been investigated nor illustrated by scanning electron microscopy. The figures given here therefore trace some of the astogenetic and ontogenetic changes in some detail.

This study is based on the descriptions of type material in the collections of the Museum national d'Histoire naturelle, Paris (MNHNP), the Natural History Museum, London (NHM), and the Naturhistorisk Rijksmuseet, Amsterdam (NRA). Specimens from the collections of the Museum of Victoria, Melbourne (MOV), the Queensland Museum, Brisbane (QM), and the Western Australian Museum, Perth (WAM), have been examined and are illustrated here.

**SYSTEMATICS**

*Siphonicytaridae* Harmer

*Siphonicytaridae* Harmer, 1957: 892.

**Diagnosis**

Erect cylindrical to flattened branching colonies, with lepralioid frontal wall development. Zooids with extensive frontal calcification, often divided into compartments by septal ridges. Ascopore located centrally within a septal ridge, distant from the secondary orifice. Avicularia adventitious, arising from marginal septular pores. Brooding unknown.

**Stratigraphic Range**

Late Eocene to Recent.

**Remarks**

*Siphonicytara* was assigned to the family *Siphonicytaridae* by Harmer (1957); it had previously been referred to the Tubocellariidae by both Busk (1884) and Bassler (1953). The Tubocellariidae includes forms with elongated peristomes, an ascopore and peristomial oviaprons, but the colony form is nodal, and neither septal ridges nor avicularia are present. The complex astogenetic and ontogenetic changes typical of *Siphonicytara* do not occur. Cheetham (1972) assigned *S. clypeata* to *Tubitabecularia*, and placed the genus in the Siphonicytaridae.

**Key to some species of Siphonicytara**

1. Some or all peristomial orifices asymmetrical, deflected to one side of the branch surface ................................................. 2

2. Peristomial orifices symmetrical, all facing outward ................................................................................. 3

2. Autozooids in whorls of 2; laterally facing zooid with basal ascopore and single basal peristomial avicularium .......... *S. serrulata* Autozooids in whorls of 3 or more; avicularia lateral, on basal peristomes only .... *S. formosa* 3. Branches cylindrical; avicularia peristomial.... 4

4. Branches 2- to 4- serial, but no larger, even late in astogeny ................................................................. 5

5. Branches 2-serial. Avicularia rare, single, disto-lateral, large, with paired condyles. Septal ridges simple, transverse .......... *S. symmetrica* Branches 2- to 4-serial. Avicularia paired, disto-lateral, large, directed medially, with serrated bar. Ascopore in shield-shaped area marked by septal ridges ........................................ *S. clypeata* 6. Avicularia proximolateral, paired, directed medially ................. *S. irregularis* (early astogenetic stages)

7. Avicularia rare, scattered, sutural only ................. *S. occidentalis* Avicularia paired, regularly present ................... 8

8. Avicularia peristomial, proximo-lateral, directed medially. Septal ridges profusely developed ....................... *S. irregularis* (later astogenetic stages)

Avicularia sutural, lateral. Septal ridges deficient ................................................ *S. arcuatis*
A review of Australian *Siphonicytara*

*Siphonicytara* Busk

*Habitat* *Siphonicytara* Busk, 1884: 101, 168.

*Tubitrabecularia* Bassler, 1934: 408 (sensu lato, see below).

**Type Species** *Siphonicytara serrulata* Busk, 1884.

**Diagnosis** As for the family.

**Description**

Colonies erect, known to be attached by rhizoids in some species. Branches unsegmented, cylindrical or somewhat flattened in cross section. Autozooids arranged in horizontal whorls of alternating longitudinal series; orifices either regularly distributed round the branch and symmetrical, facing outward, or deflected to one face of the branch, asymmetrical. In some species the resulting frontal and basal faces of the branch have zooids of different morphologies. Primary calcified orifices D-shaped or oval, not well defined. Peristomes long, prominent or immersed in calcification, secondary orifices round. Frontal shields lepralioid (cryptocystidean), imperforate centrally, with large marginal septular pores which may develop into areolae of wide extent and great complexity later in ontogeny. Ascopore present, opening in the interior close to the proximal edge of the primary orifice, but, at the exterior, appearing to open at the centre, or even at the proximal end of the exposed frontal shield. Raised calcified septal ridges variously extensive and prominent, sometimes extending round the secondary orifice, from the proximal side of the peristome to the ascopore and beyond, surrounding the ascopore, and from the ascopore to the lateral margins of the frontal shield. Ontogenetic changes considerable, with thickening of frontal calcification, or with calcification of septal ridges extending into the hypostegal coelom and producing a honeycomb-like appearance, with areolae anastomosing and dividing. Primary avicularia present early in ontogeny, arising from lateral frontal septular pores, often placed near the peristome, occasionally lateral and frontal. Subsequent avicularia often sutural, arising late in ontogeny at the margins of the zooids, variously orientated. Mandibles rounded or triangular, hinged on paired condyles or a complete bar, which usually has a protuberance (ligula) on its palatal side, or may be serrated, with several prominences. Ovicells not seen here or described in any species, assumed to be peristomial and immersed. Rhizoids arising from marginal frontal septular pores late in ontogeny in some species.

**Remarks**

The effects of ontogenetic thickening of the calcification in most species is marked. In some, the early and late states may have virtually no recognisable feature in common. This is particularly the case in *S. irregularis*, where the septal ridges become irregularly convoluted and Anastomose, obscuring the outline of the underlying zooid frontals. In addition, the occurrence of large sutural avicularia in this species makes it difficult to trace the position of the ascopores. The raised septal ridges in Recent species were investigated by Harmer (1957), who illustrated and described the astogenetic and ontogenetic changes at the growing tips of the branches. The septal ridges include cuticular traces, and these appear to be derived from the insertion of the frontal cuticle as the septal ridges grow into the extrazoidal coelom and deepen with ontogenetic thickening. In all species other than *S. irregularis* and *S. occidentalis*, the relationship of the septal ridges with secondary orifices and ascopores remains visible, even in late ontogenetic stages. The septal ridges do not all mark the boundaries of zooid frontals, but often resemble the lozenge-shaped areas of the anascan Cellariidae (see Harmer, 1926: 335).

*Siphonicytara serrulata* Busk

*Siphonicytara serrulata* Busk, 1884: 101, plate 15, figures 2, 2b; Canu and Bassler, 1920: 549, figure 162; Harmer, 1957: 893, plate 61, figure 10.

**Type Material**

**Lectotype**

NHM 1897.12.9.446 [figured by Busk (1884)], Challenger Stn 196, approx. 0°48'S, 126°58'E, east of Celebes, 1508 m (825 fathoms).

**Paralectotype**

NHM 1897.12.9.447, collecting data as above, transverse section, see Harmer (1957).

**Description**

Branches slightly flattened, with alternating whorls of two zooids, one with peristome facing laterally and slightly frontally, the other with the peristome symmetrical and facing frontally. Ascopore of frontally facing zooid is frontal, placed in a distinct area outlined by septal ridges. Ascopore of laterally facing zooid is basal, also placed within an area. Avicularia small, rounded, confined to a single one on the basal side of the peristome of each laterally facing autozooid. Rhizoids arising from above a frontal septular pore of a laterally facing zooid, on the basal side.

**Remarks**

Harmer (1957) redescribed *S. serrulata*, and was the first to note the presence of small avicularia on
the peristome of the laterally facing autozooids. The septal ridges are not very prominent, and outline only the area surrounding the ascopore.

**Distribution**
Cebes (Sulawesi), 1508 m.

**Siphonicytara formosa** Harmer
*Siphonicytara formosa* Harmer, 1957: 893, plate 61, figures 1–5, 7.

**Type Material**
- **Lectotype**
  NRA Siboga Stn 156, approx 0°29.2’S, 130°5.3’E, west of Waigeu Id, Northwest New Guinea (Irian), 469 m.
- **Paralectotype**
  NHM 1986.1.12.1, collection data as above.

**Description**
Branches slightly flattened, autozooids in alternating whors of three and four, four and four, or four and five zooids, widest just before a bifurcation. Alternating frontal and latero-frontal zooids respectively with nearly symmetrical or frontally deflected peristomes; ascopores slightly raised, flanked by paired frontal septular pores, avicularia absent. Latero-basal zooids with long, free peristomes directed towards frontal surface; ascopores basal, raised, with a lip, and flanked by paired frontal septular pores. Avicularia peristomial, lateral and basal, variously orientated. Central basal longitudinal series of zooids with very long peristomes directed alternately to one or the other side, ascopores raised, with a lip; avicularia very large, lateral and peristomial, but subrostral chambers encroaching on frontal shield, surrounded by septular pores. Avicularian mandibles subtriangular to rounded, bar stout, curved, but without ligula. Rhizoids arising on basal surface, from one of the frontal septular pores surrounding an avicularian chamber, sometimes paired, passing downward and becoming apposed to form a supporting stalk.

**Remarks**
According to Harmer (1957), the colony originates as a narrow branch of alternating, uniserial autozooids, supported by rhizoids. Most branches are quadriserial, but in those with alternating series of 3 and 4 autozooids, the basal surface is partially composed only of the frontal surfaces of the latero-basal pair of zooids, without an intervening basal zooid. Septal ridges are prominent early in ontogeny, but become less noticeable as the frontal calcification thickens.

**Distribution**
New Guinea (Irian), 469 m.

**Siphonicytara cylindrica** Harmer
*Siphonicytara cylindrica* Harmer, 1957: 895, plate 61, figures 6, 8, 9, 11, 12.

**Type Material**
- **Lectotype**
  NRA Siboga Stn. 119, approx. 1°33.5’N, 124°41’E, north Celebes (Sulawesi), 1901 m.
- **Paralectotype**
  NHM 1986.1.12.2, collecting data as above.

**Description**
Branches stout, with orifices regularly distributed in whors of 4 and 5 autozooids. Free peristomes short, symmetrical, ascopores with tubular orifice flanked by paired frontal septular pores. Avicularia large, arising from a septal pore distal to the peristome; subrostral chamber surrounded by septal ridges at first, with frontal septular pores; mandible subtriangular to rounded; bar with a small ligula. Small rounded sutural avicularia developed late in ontogeny, becoming numerous.

**Remarks**
*Siphonicytara cylindrica* differs from *S. clypeata* in its more robust size, and in the occurrence of only one peristomial avicularium on the distal side of the orifice. It differs from *S. occidentalis* in the cylindrical form of the branches, and the large number of sutural avicularia developed late in ontogeny, and from *S. symmetrica* in its much thicker branches and numerous avicularia with ligulate bar. Harmer did not find any rhizoids; it is possible that they occur on all sides of the branch, as in *S. occidentalis* (see p. 317). The septal ridges are prominent early in ontogeny, surrounding both the ascopore area and the avicularian subrostral chamber.

**Distribution**
Celebes (Sulawesi), 1901 m.

**Siphonicytara symmetrica** David and Pouyet

**Type material**
- **Holotype**
  MNHN, Safari Stn. I, 88 (CP04), approx. 30°S, 50°E, southeast of Madagascar, 4297 m.
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**Description**
Branches cylindrical, autozooids in alternating whorls of two zooids, rising to three before a bifurcation. Free peristomes slightly raised, circular; ascopores with a raised rim; four to seven lateral marginal septular pores, enlarged to form areolae. One undulating septal ridge passing horizontally across the distal end of each zooid, and another passing between the ascopore and the orifice. Avicularia rare, lateral and oral, large, with a swollen subrostral chamber and paired condyles. Peristome next to avicularium deflected to one side.

**Remarks**
*Siphonicytara symetrica* resembles *S. cylindrica* in the regularity of zooid orientation and its oral avicularium, but differs in the rarity of avicularia and in their paired condyles. The occurrence of *S. symetrica* provides yet another example of links between the Recent deeper-water fauna of southeast Africa, and that of the Australasian Tertiary (Hayward and Cook, 1983: 147), and underlines the antiquity of this link.

**Distribution**
Off southeast Madagascar, 4297 m.

*Siphonicytara irregularis* (Maplestone)  
Figures 1A-E, 2A-D


*Microporella elevata*:
Waters, 1881: 330, plate 17, figures 63,64, plate 18, figure 90; Waters, 1882b: 503, 508 (listed); Waters, 1883: 427, 436 (listed); Waters, 1885: 296, plate 7, figures 6,9.

*Tessaradoma elevata*:
MacGillivray, 1895: 66, plate 9, figure 20 (as figure 28 on p. 66).

*Micronella irregularis* Maplestone, 1902: 21, plate 2, figure 11.

*Tubitrabecularia proditor* Canu and Bassler, 1935:18, plate 4, figure 10.

*Tubitrabecularia elevata*:

**Material Examined**

*Holotype of Micronella irregularis*  
MOV P10200, Mitchell River, near Bairnsdale, Victoria (Miocene), Maplestone Collection.

*Other material*  
MOV P27667 locality unknown (MacGillivray);  
MOV P73195, Allot.1, Parish of Glenaulin (Brown) and see below.
Figure 1  *Siphonicyctara irregularis* (Maplestone, 1902), Balcombe Bay, Miocene. (A) Collage of flabelliform branch developed by frontal budding from cylindrical early astogenetic stage (arrowed): Scale=1.0 mm. (B) Distal end of colony showing frontally budded zooids: Scale=0.25 mm. (C) Zooids from central region showing septal ridges becoming obscured by thickening calcification of frontal shield. Note relative positions of secondary orifice (o) and its proximal ascopore (a), and oral avicularium with ligula (av): Scale=0.25 mm. (D) Zooids from proximal region showing development of a mound: Scale=0.25 mm. (E) Interior of frontal shield showing primary orifice (o) and ascopore (a). Note opening of oral frontal septular pores (s) leading to avicularian subrostral chamber: Scale=0.20 mm.
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Figure 2  *Siphonicytara irregularis* (Maplestone, 1902), Balcombe Bay, Miocene. (A). Zooids of the last 6 astogenetic generations of a flabelliform, bilaminar colony, showing small marginal areolae becoming obscured by development of septal ridges and secondary areolar spaces: Scale=1.0 mm. (B) Cylindrical proximal end of the same colony (Compare *S. clypeata*, Figure 3A), Showing earlier astogenetic and ontogenetic states: Scale=1.0 mm. (C) Zooids enlarged from A, showing secondary areolar spaces and large avicularia: Scale=0.50 mm. (D) As above, later ontogenetic stage: Scale=0.50 mm.

described and illustrated the septal ridges and the internal relationships of the ascopore and primary orifice. The attribution of *S. irregularis* to *Tessaradoma* (as *T. elevata*) by MacGillivray was based on the occurrence of an ascopore ('trypa'), and *T. elevata* was included in the genus with *T. magnirostris* (MacGillivray). In his discussion of *Tessaradoma*, Cheetham (1972: E6) implied that all the fossil species assigned to this genus by MacGillivray in 1895 belonged instead to the genus *Tubiporella* Levinsen. It is true that *T. magnirostris* is referable to *Tubiporella* (see Cook and Chimonides, 1981, for discussion), but the second species which MacGillivray described, *T. elevata*, is definitely assignable to *Siphonicytara irregularis*. This in no way alters Cheetham's later statement that the genus *Tessaradoma* does not occur in Australia (see also Lagaaij and Cook, 1973).

Maplestone (1902) described his single specimen of *Mucronella irregularis* as encrusting, and noted that the zooids had a small proximal mucro on the edge of the peristome, with a pore below it. In spite of these characteristics, which do not seem typical of *Siphonicytara*, his description of the surface ridges, which he noted 'do not appear to indicate the margins of the zooecia', and his figure, suggest that his material belongs to the genus. Our examination of the type specimen (MOV P10200)
confirms this. It is probable that the small pore mentioned by Maplestone (1902) was not the ascopore, which he did not recognise, but one of the irregular areolar spaces left between the circum-oral septal ridges and the peristome in a highly calcified, and somewhat worn, specimen.

Canu and Bassler (1935) introduced Tubitrabecularia proditor for specimens from the Victorian Miocene which had wide, flattened branches. Neither the description nor the retouched photograph gives any detail of peristomial avicularia, but an ascopore is present. 'Trabeculae' were mentioned in the description: these are the equivalent of septal ridges. Cheetham (1972) assigned T. proditor to Tubitrabecularia clypeata. His Eocene material may have included more than one species (see p. 315).

As M. elevata, S. irregularis has been recorded from Mount Gambier, Curdies Creek, Baimsdale, Muddy Creek, Spring Creek, River-Murray Cliffs, and, as Tessaradoma elevata, from Schnapper Point (presumably Balcombe Bay).

The astogenetic and ontogenetic changes occurring in S. irregularis are more marked than in any other species of Siphonicytara. The early astogenetic changes are rarely preserved; they consist of portions of cylindrical branches with two to eight zooids per whorl, similar to those of S. clypeata in general appearance. They differ in being more robust, in having much more prominent septal ridges, and in the more proximal position of the lateral peristomial avicularia. In some colonies, intercalary series of autozooids are rapidly introduced, and within seven generations, a biserial branch has become a bilaminar lobe with eight to ten autozooids in each horizontal whorl (Figures 2 A, B). In other colonies, a similar, quadriserial cylindrical branch is transformed in an entirely different manner. The first change is ontogenetic, with considerable deepening of the septal ridges, and increasing irregularity of the areolar spaces. Subsequent increase of frontal calcification obscures the septal ridges and is followed by an astogenetic change which results in the covering of the primary cylindrical branch by a flattened branch with many more zooids per whorl. This change may be the result of overgrowth by distal budding from a focus of frontally budded zooids at the base of the branch (Figure 1A). This would be similar to mamilliform growth in many encrusting cheilostomes. Alternatively, there may be a series of distally directed episodes of frontal budding from the zooids of the cylindrical part of the branch. In fact, a combination of these processes probably occurs. The large, bilaminar expanses (which may attain 8 x 10 mm in size) may show further thickening of calcification, or deepening of the septal ridges, with production of large sutural avicularia, which are irregularly orientated, all over the surface of the colony. The final stage consists of the development of clusters of autozooids on the surface of a branch, which becomes greatly thickened, forming mound-like areas of calcification (Figure 1D). The thickening eventually obscures orifices, ascopores and most areolae. In fragmented assemblages, these mounds are less easily fractured than surrounding areas of a branch, and may be preserved in isolation. The mounds are at first extremely difficult to recognize as more than worn bryozoan fragments, and are completely different from the earlier astogenetic and ontogenetic stages of S. irregularis. It is possible that some of these mound-like clusters of zooids may be derived from frontal extensions of existing zooids, rather than from interzoooidal frontal buds (see S. occidentalis, p. 318). Canu and Bassler (1935) suggested that these were ovicelled zooids, but there is no positive evidence of this (see also Cheetham, 1972).

Generally, the range of variation exhibited in specimens from any one locality is very wide. Among the large numbers of colony fragments from Balcombe Bay, a significant proportion have autozooids with one, very large, elongated avicularium, rather than a pair of smaller avicularia. Well preserved, quadriserial branches from Browns Creek rarely exhibit long peristomes, some with a large avicularium placed on one side.

Distribution
Bairnsdale; Balcombe Bay; Batesford; Bird Rock; Browns Creek; Cape Otway; Grices Creek; Mount Gambier; Mount Schanck; Muddy Creek; Narrawaturk Bore 2; Princetown (Also reported from River Murray Cliffs, Curdies Creek, Spring Creek).

Siphonicytara clypeata (Waters)
Figures 3A–C
Porina clypeata Waters, 1881: 332, plate 17, figure 67; Waters, 1882a: 268; Maplestone, 1904: 213 (listed).
Tubitrabecularia clypeata (part): Cheetham, 1972: E17, plate 6, figure 2.

Material Examined
Specimens from the Miocene of Victoria; including Balcombe Bay, Cooriemungle, Fyansford, Muddy Creek, Narrawaturk Bore 2, Paaratte Bore (Port Campbell), Princetown, and from South Australia, including Mount Schanck.

Description
Branches cylindrical, with whorls of two to four alternating zooids. Free peristomes raised, symmetrical, not very long; ascopore raised and
tubular. Septal ridges raised but not prominent, shield-shaped area surrounding ascopore distinct and including a pair of frontal septular pores. Primary peristomial avicularia paired, disto-lateral to peristome, orientated medially; rostra and mandibles subtriangular, bar serrated. Small, paired oval or spatulate avicularia, orientated proximally, occasionally developed above lateral areolae.

Remarks

Siphonicytara clypeata is a well-marked species, and there is little difference between the specimens described from the Miocene of Victoria by Waters (1881, 1882a), and those illustrated by Cheetham (1972) from the Upper Eocene of Eua, Tonga. Siphonicytara clypeata is not common in Australian samples, although it has a wide occurrence among the localities examined. Waters (1881, 1882a) mentioned it only twice, from Curdies Creek, southwest Victoria and from Mount Gambier, South Australia (Miocene), and Maplestone (1904: 213) listed one additional record he had found, from the Mitchell River, west of Bairnsdale, eastern Victoria (Miocene). MacGillivray (1895) gave no description of S. clypeata. Some specimens may have been confused with those of young, cylindrical branches of S. irregularis. These are more robust, and may be distinguished by the distinctly more proximal position of the peristomial avicularia, and by the much more prominent septal ridges.

Waters (1881) gave a detailed description which included discussion of the ascopore and septal ridges, and figured the avicularia. Cheetham (1972) included T. proditor Canu and Bassler (1935) in the synonymy of his T. clypeata. His description mentions specimens with slightly flattened branches with more than four autozooids per whorl. These certainly resemble T. proditor, but not S. clypeata. It is therefore reasonably certain that Cheetham’s (1972) material included more than one species, S. clypeata, which was figured, and another species resembling S. irregularis.

Distribution

See above; also Mitchell River, Victoria; Mount Gambier, South Australia and Eua, Tonga.

Siphonicytara airensis (Maplestone)

Figures 4A–C

Macronella airensis Maplestone, 1902: 22, plate 2, figure 12; Maplestone, 1904: 212 (listed).

Bathosella laticella Canu and Bassler, 1935: 31, plate 9, figure 2.

Material Examined

*Lectotype*

MOV P10201, Aire Coastal Beds, Victoria (exact location not specified. Eocene or Oligocene).

*Other Material*

Browns Creek (Late Eocene).

Description

Branches subcylindrical to bilaminar and slightly flattened; autozooids in lateral series of four to eight, in alternating longitudinal rows, outlined by shallow grooves, septal ridges shallow or virtually absent. Primary orifice large, straight distally and rounded proximally, proximal ascopore subtriangular. Secondary orifice circular or subtriangular and straight proximally, sometimes raised proximally, but not prominent; peristomial calcification very thick. Ascopore in an indistinct proximal area, outlined by a shallow septal ridge late in ontogeny, when it is often flanked by paired areolae derived from frontal septular pores. Marginal septular pores four to six, developing as rounded areolae. Avicularia paired, lateral, small, sutural, rounded and orientated proximo-laterally with a complete bar; other similar avicularia developed above areolae later in ontogeny.

Remarks

Maplestone's (1902) description of *M. airensis* did not mention the ascopore, which also was not figured. His drawing and the lectotype specimen, however, confirm that *M. airensis* is referable to *Siphonicyctara* and identical with material collected from Browns Creek, illustrated here. *Siphonicyctara airensis* is distinguished by the virtual lack of raised septal ridges, and by its large, rounded or subtriangular secondary orifices. The dimensions of both primary and secondary orifices are greater than those of *S. irregularis* and *S. clypeata*. The significance of the circular orifices is unknown, and investigation requires additional well preserved specimens. Although there are no raised septal ridges, the ascopore and the zooids in general are outlined by shallow grooves in the calcification, marking the former presence of cuticular insertions. *Siphonicyctara airensis* is clearly assignable to *Siphonicyctara*, but it also bears some similarity to a species described by Cheetham (1975), as *Tubucella* sp. 2, from Early Eocene deposits in the northwestern Pacific (see p. 320). *Tubucella* sp. 2 differs in its lateral oral avicularia and more porous frontal shield.

The description and illustrations given by Canu and Bassler (1935) for two species from the Aire Coastal Beds, *Bathosella laticella* and *B. bulbosa*, suggest that only one taxon is involved. Both figures have been somewhat heavily retouched, but show a proximal ascopore in several zooids, and paired...
A review of Australian *Siphonicytara*

lateral avicularia, particularly in the figure of *B. bulbosa*. The genus *Bathosella* was introduced by Canu and Bassler (1917: 43) for *Mucronella aspersa* Ulrich, from the very Early Eocene of Maryland and New Jersey. According to their expanded description (1920: 405, plate 1, figures 27-31), *B. aspersa* was encrusting, the zooid orifice had a proximal tooth, and ovicells with a frontal entoecial area were present. Neither *B. laticella* nor *B. bulbosa* have any of these characters, and both greatly resemble *Siphonicytara airensis*. Without examination of the type or figured material it is not certain that these species are junior synonyms of *S. airensis*, but it is significant that the holotypes of all three forms are from the same locality. Brown (1958: 69) examined the type specimens and placed *B. laticella* in synonymy with *B. bulbosa*.

**Distribution**

Brown's Creek; southwestern Victoria, Late Eocene.

*Siphonicytara occidentalis* sp. nov.

Figures 5A–C, 6A–D

**Material Examined**

**Holotype**

QM GH3217 CSIRO sample 134/DM4/63, 33°40'S, 114°28'E, southwest of Bunbury, Western Australia, Australia, 137 m.

**Paratypes**

QM GH1022 CSIRO sample 131/DM4/63, 27°40'S, 113°03'E, west of Kalbarri, Western Australia, 128 m. QM GH1113 CSIRO sample 134/DM4/63, details as for holotype. QM GH1181 CSIRO sample 141/DM4/63, 32°00'S, 115°08'E, west of Fremantle, Western Australia, 119 m. MOV F52871, part of QM GH1113. WAM, part of QM GH1113.

**Other material**

MOV Locality ‘Franklin’ GAB128, 35°7'S, 116°52'E, 59 m, GAB130, 35°7'S, 115°59'E, 100 m.

**Description**

Branches flattened, bilaminar, with 10–12 autozooids per horizontal whorl, rising to 14–16 before a dichotomy. Primary orifice semicircular, secondary orifice oval, free peristomes symmetrical, moderate. Septal ridges prominent, surrounding the peristome and ascopore, which becomes flanked by paired areolae. Avicularia absent over large areas of the colony, when present, usually small, mandibles and rostra rounded, ligula absent. Rhizoids arising above lateral septal pores of zooids near the base of a branch, from both surfaces, running proximally but not forming a stalk as in *S. formosa* (see p. 310).

**Remarks**

*Siphonicytara occidentalis* resembles *S. irregularis* in

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Figure 5  *Siphonicytara occidentalis* sp.nov., Western Australia, Holotype QM GH3217. (A) Part of branch: Scale=2.0 mm. (B) Zooid enlarged to show secondary orifice (o) and ascopore (a), note thickening around areolae and prominence of septal ridges: Scale=0.50 mm. (C) Group of zooids with small oral avicularia: Scale=1.0 mm.
colony form, and in the prominence of the septal ridges. The material does not show any sign of the massive thickening of calcification occurring in *S. irregularis*, however. The septal ridges are deep and form a network over the entire frontal shields. Avicularia are very rare, scattered and small, and they are sutural, arising late in ontogeny above lateral marginal septular pores. Very rarely one of the avicularia is enlarged, with a subtriangular mandible and a spout-like rostrum. The bars of all avicularia are delicate and lack ligulae. One colony shows a cluster of zooids similar to those found in *S. irregularis*. In this cluster (Figures 6A, B) the peristomes and surrounding septal ridges have elongated considerably. This suggests that a similar process in *S. irregularis*, followed by an increase in frontal calcification filling in the areolar pores and irregular areolar areas, is the origin of the mound-like clusters of raised zooids (see p. 314).

Some branches have numerous rhizoids, as many as eight originating from each zooid, concentrated in zones surrounding the lower part of the branch. Cuticular zooid linings, similar to rhizoids, are also present at the proximal end of broken branches.
These, together with evidence of regeneration of growing tips of branches suggest that detached fragments and colonies may be able to maintain an independent existence.

Distribution
Western Australia, 119–137 m.

Etymology
Occidentalis (Latin), western, referring to its occurrence from Western Australia.

**DISCUSSION**

Fifteen species of *Siphonicytara* are now known. Twelve Recent taxa occur in two speciose groups, four from the East Indian, and six from the New Caledonian regions. There is one isolated record from the western Indian Ocean, and a group of five from Western Australia. Bathymetrically, *S. symetrica* is by far the deepest occurrence, at over 4000 m depth. *Siphonicytara cylindrica*, *S. serrulata* and *S. mosaica* all occur from less than 2000 m, and all other species are from less than 1000 m depth. *Siphonicytara occidentalis*, from Western Australia has the shallowest distribution, less than 150 m depth.

The three fossil species all occur from the Late Eocene, two having a range extending to the Miocene of southeastern Australia.

Colonies are erect, cylindrical or slightly compressed and almost bilaminar, and often branched. Five of the Recent species (*S. serrulata*, *S. formosa*, *S. armata*, *S. vittata* and *S. occidentalis*) are known to be anchored by rhizoids. Many deep-water taxa have a similar mode of growth, with up to nine species belonging to erect genera such as *Notopites*, *Cornucopia*, *Himantozoum*, *Chelidozoum*, *Ithyaria*, *Diplonotos*, *Donosclerus*, *Hawelliporina* and *Tetraplaria*, as well as reteporiform species of *Idociyum* and *Reteporella* (Gordon and d’Hondt, 1997; Gordon, 1993; d’Hondt and Gordon, 1996). The deepest locality, from southeast of Madagascar, provides a large number of accompanying species, including 16 erect taxa. *Species of Columnella*, *Himantozoum*, *Petalostegus*, *Bifaxaria* and *Tessaradoma* are present, and in addition, specimens of the monoserial stenolaemate *Anguisia verrucosa*, which was previously known only from deep-water in the northeastern Atlantic and the Mediterranean (David and Pouyet, 1986). The largest number of species accompanies the specimens of *S. insolta* from Albatross Stn 5574. Of the 31 species present, 11 are known to be members of ‘sand faunas’ and are anchored by rhizoids. These include species of *Conesuchrella*, *Flabellopora*, *Zenglopora* and *Parmularia* (see Canu and Bassler, 1929).

The fossil species, too, are found with a similar range of colony forms and are in multispecific assemblages. In the samples from Victoria and South Australia, many species of are known to have occurred on soft, unstable bottom sediments. So many Australian fossil species have very close, or even apparently identical representatives in Recent seas, that their ecological parameters may be inferred with a fair degree of confidence. In complete contrast to nearly every Recent assemblage including *Siphonicytara*, none of these fossil species can be regarded as from deep-water conditions, but resemble those from Western Australia.

Cheetham (1972) considered his Eocene specimens of *S. clupeata* from Tonga to represent part of a shallow-water, allochthonous element of his assemblage. This contained 18 species, five of which (belonging to the genera *Bifaxaria*, *Tessaradoma* and *Spiroporina*) were autochthonous, deep-water forms, which contributed the greater part of his material. In spite of the shallow-water associations of the Western Australian Recent *S.
occidentalis, and of the Victorian fossil specimens, it is possible to regard S. clypeata as a cryophilic species (or at least a representative of a cryophilic genus) which descends to deeper water in low latitudes. In this case, the Eocene record from Tonga, from a tropical locality, might instead be regarded as one of the deep-water, autochthonous species in the assemblage.

The Didymosellidae shows some interesting analogues with the Siphonicytaridae, although the two families do not seem to be closely related, and share a long, but distinct, fossil history. Among the erect fossil forms of Didymosella, D. porosa (Stoliczka) has orifices which are deflected to the frontal side of the branch, whereas those of D. clypeata Canu and Bassler are not (Cook and Chimonides, 1981). The frontal thickening of the lepraloid shields in Didymosella and Tubiporella is considerable, and in T. magnirostris consists of a deep network of areolae and intervening calcification, in which the spiramen is difficult to recognise, as is the ascopore in S. irregularis. As in the Didymosellidae, almost all the calcified walls in Siphonicytara are interior walls, which have an overlying coelom and cuticle separating them from the environment. In S. irregularis and S. occidentalis, even the free peristomes are in part surrounded by coelom. However, none of the species of Siphonicytara develop basal coelomic complexes as in the Didymosellidae.

Two ancient genera which appear to have closest relationships with Siphonicytara are Gastropella Canu and Bassler, 1917 and Tubucella Canu and Bassler, 1917. Both genera have been included in the family Tubucellariidae, but both could be reassigned to the family Siphonicytaridae. Gastropella was introduced for G. ventricosa (see Canu and Bassler, 1917: 38, plate 4, figure 3, and 1920: 320, plate 6, figures 7–12) from the Midwayan (Early Eocene) of Arkansas and Georgia, U.S.A. It resembles the cylindrical species of Siphonicytara in colony form, and in its tubular peristomes, central ascopore, and marginal septular pores which form large areolae. The type species has an umbonuloid frontal shield, and appears to be more closely related to the genus Tessaradona (D.P. Gordon, personal communication).

Tubucella was introduced for T. mainillaris (Milne-Edwards), a European species ranging from Early Eocene to Miocene. T. sp. mainillaris was redescribed by Cheetham (1966: 85, figures 62–64), from the Late Eocene Bracklesham Beds of the United Kingdom. It is closely similar in appearance to T. monilifera Canu and Bassler (1917: 63, plate 5, figure 9), from the Late Eocene of North Carolina. The wide Eocene to Miocene distribution of Tubucella was discussed by Cheetham (1975, Table 3), who listed all previous records. Colonies of Tubucella have cylindrical to compressed, even flabellate branches. The zooids have numerous frontal pores, many of which may be ‘carried up’ from marginal areolae (Cheetham, 1975, plate 2, figure 2). Species have raised, circular peristomial orifices, often accompanied by lateral avicularia. The ascopore was noted by Cheetham (1975) to be placed in a distinct region of the frontal shield, divided by a ‘presumably cuticular’ line from the orifice region. Species of Castropella and Tubucella have peristomial ovicells, and in Tubucella, the brooding zooids tend to occur in centrally placed rows. They are often enlarged, with distinctive secondary orifices. As mentioned above, Tubucella sp. 2 Cheetham (1975: 842, plate 3, figures 1–2, and plate 4, figure 5), from the Early Eocene of the Koko Seamount (approximately 35°N, 172°E), resembles Siphonicytara airesensis, although it has a more porous frontal shield, and lateral oral paired avicularia. The ‘dimorphic’ rounded orifices found in S. airesensis are not placed at the centre of the branch, and require further investigation of well preserved material. It is presumed that all species of Siphonicytara have concealed peristomial ovicells, but none have been reported.

There is no evidence of any descendant sequences in Siphonicytara. The colonies of S. clypeata and S. irregularis show that a wide range of growth form already occurred in the Late Eocene. Colonies with a similar diversity in branch structure and zooid arrangement occur in the Recent species S. insolita and S. occidentalis respectively. One trend which appears to have developed since the Tertiary is the formation of branches with frontal and basal (abfrontal) sides. The differences are slight in S. excentrica and S. mosaica, but distinct in S. glabra and S. viitata (Gordon and d’Hondt, 1997), and reach their greatest development in S. serrulata.

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REFERENCES

A review of Australian Siphonicytara


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APPENDIX

Details of Australian Tertiary localities mentioned in the text

Aire Coastal Beds: Brown (1958: 29) noted that this locality cannot be more precisely stated, but the evidence from Maplestone's (1904) faunal lists and from the localities quoted by Canu and Bassler (1935), suggests that this is about the same horizon as the beds at Cape Otway. Age: Eocene or Oligocene.

Bairnsdale (Skinner's): Mitchell River bank, about 12 km west of Bairnsdale, Victoria. Lat. 37°47.9'S, Long. 147°29.5'E. Age: Miocene.

Balcombe Bay: Also known as Fossil Beach, Mornington, Mount Martha and possibly 'Schnapper Point' (MacGillivray); on coast of Port Phillip Bay, about 3 km south of Mornington, Victoria. Lat. 38°14.5'S, Long. 145°01.7'E. Fyansford Clay. Age: Balcombian; Middle Miocene, (Langhian).

Batesford Quarry: Upper levels of Batesford Limestone Quarry, 7 km west of Geelong, Victoria. Lat. 38°06.5'S, Long. 144°17.3'E. Fyansford Clay. Age: Balcombian; Middle Miocene, (Langhian).

Bird Rock: Coastal section, about 3 km west of Torquay, Victoria. Lat. 38°21.4'S, Long. 144°17.8'E. Jan Juc Formation. Age: Early Oligocene; Late Oligocene, (Chattian). Also known as Spring Creek.


Cape Otway: Also Point Flinders, Locality AW1. Coastal section 2 km northwest of Cape Otway, Victoria. Lat. 38°51.1'S, Long. 143°29.5'E. Glen Aire Clay. Age: Early Oligocene, (Rupelian/Latdorfian).

Cooriemungle area: Road cuttings about 18 km north of Princetown, Victoria. Lat. 38°32.4'S, Long. 143°08.1'E. Gellibrand Marl. Age: Balcombian, Middle Miocene, (Langhian).

Curdies Creek: This is the locality name applied to the bryozoans described by Waters (1881). The original paper mentions 'Yarra Yarra', which is the river on which Melbourne is located, and from which no bryozoan fossil localities have been recorded. Later publications (eg MacGillivray, 1895) have used the locality Curdies Creek for this collection. The coastal section at the mouth of the Curdies River exposes Late Miocene limestone with a sparse bryozoan fauna. Inland sections are generally in limestone, but some of the muddy sediments of the Gellibrand Marl are exposed near Timboon. However, it is believed that the sample is more likely to have come from coastal sections, which were much more accessible at that time. If the sample was obtained from the coastal exposure, it almost certainly was close to the locality listed as 'Princetown' below.

Fyansford. This locality was mentioned by Maplestone (1904), and is almost certainly in the same area as Batesford Quarry.


Grices Creek: Also known as Gunyong Creek; on the coast of Port Phillip Bay, about 8 km north of Mornington, Victoria. Lat. 38°11.9'S, Long. 145°03.9'E. Fyansford Clay. Age Balcombian (some material may be Bairnsdalian); Middle Miocene, (Langhian).

Mitchell River, see Bairnsdale.

Mount Gambier: Abandoned quarry on road to Port MacDonnell, about 7 km south of Mount Gambier, South Australia. Lat. 37°53.5'S, Long. 140°43.2'E. Gambier Limestone. Age: Early Miocene, (Langhian).

Mount Schanck: Limestone quarry about 1 km west of Mount Schanck, about 15 km south of Mount Gambier, South Australia. Lat. 37°57'S, Long. 140°43.2'E. Gambier Limestone. Age: Early Miocene, (Langhian).

Muddy Creek: Clifton Bank, Muddy Creek, 8 km west of Hamilton, Victoria. Lat. 37°44.6'S, Long. 141°56.4'E. Muddy Creek Marl (= Gellibrand Marl). Age: Balcombian, Middle Miocene, (Langhian).


Paaratte No.1 Bore. Mines Department bore in the Parish of Paaratte, located in the village of Port Campbell, Victoria. Lat. 38°36.8'S, Long. 143°00.0'E. Age: Middle Miocene.

Princetown (Gigantocypraea locality): Coastal section, about 2 km west of Princetown, Victoria. Lat. 38°41.9'S, Long. 143°08.3'E. Gellibrand Marl. Age: Balcombian, Middle Miocene.

River Murray Cliffs. A large number of fossil localities are exposed between Tailem Bend and Overland Corner, in South Australia. It is suspected that the material described by Waters (1885) may have come from the region of Murray Bridge. Age: Miocene.

Schnapper Point; see Balcombe Bay.

Spring Creek; see Bird Rock.

Waurn Ponds. Several quarries and other exposures 10 kilometres southwest of Geelong, Victoria.
Salticidae (Arachnida: Araneae) from the Oriental, Australian and Pacific regions, XIV. The genus *Adoxotoma* Simon

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Abstract — The endemic Australian genus *Adoxotoma* is reviewed. Of five species treated, *A. bargo*, *A. hannae* and *A. justyniae* are described as new. Males of the genus are described for the first time. The relationships of *Adoxotoma* are discussed and distribution maps are given.

INTRODUCTION
The genus *Adoxotoma* was described by Simon in 1909. It was represented by two species, based upon three females, known only from the south-western corner of Western Australia. Because of this, the genus had long been thought of as rare and endemic to that area. However, recent biodiversity surveys conducted by the Australian Museum, Sydney and the Western Australian Museum, Perth, have revealed new species from a number of localities in New South Wales and Western Australia.

Since its original description, *Adoxotoma* has been reviewed by Wanless (1988), and Davies and Żabka (1989). As emphasised by Wanless, the limited morphological and distributional data has made a complete description of *Adoxotoma* impossible. The new data on distribution and morphology provided here – especially on female internal genitalia and male palpal structures – has allowed a taxonomic re-assessment of the genus and its relationships.

MATERIALS AND METHODS
Methods of specimen examination are as described in Żabka (1991b).

The material was collected in New South Wales (NSW) and Western Australia (WA) and is deposited in the following collections: Australian Museum, Sydney (AMS); Museum National d'Histoire Naturelle, Paris (MNHN); Western Australian Museum, Perth (WAM); Museum für Naturkunde der Humboldt Universität, Berlin (ZMH); Zoologisches Institut und Zoologisches Museum, Universität Hamburg (ZMH).

Abbreviations: AEW — anterior eyes width, AL — abdomen length, CL — cephalothorax length, CW — cephalothorax width, EFL — eye field length, PEW — posterior eye row width.

SYSTEMATICS
Family Salticidae Blackwall, 1841
Genus *Adoxotoma* Simon, 1909


Type Species *Adoxotoma nigroolivacea* Simon, 1909, by subsequent designation of Bonnet (1955).

Diagnosis
Differs from other genera of Astieae by almost uniformly dark colour pattern, male abdominal scutum, enlarged first legs, including coxae and trochanters, first tibiae and metatarsi heavily armed with long spines. Genitalia of both sexes distinctive.

Description
Small to medium spiders, 3.50–5.50 mm in body length. Cephalothorax (Figure 3J) rather low, widest at the third legs, with gentle posterior slope. Thoracic part longer than cephalic part. Fovea sulciform, located in the posterior half of the carapace – well behind the eye field. Anterior eyes in one row, posterior medians prominent, posterior laterals set on tubercles. Abdomen oval, in males with shiny black scutum and 2 distinctive median depressions (apodemes). Clypeus narrow. Chelicerae with 2 prolateral and 2–4 retrolateral teeth, the latter often fused at the base in fissidentati manner. Maxillae elongate, in males with anterolateral extension (Figure 3E). Sternum cordate. First legs (Figure 1C) moderately strong and long, armed with two rows of long ventrolateral spines on tibiae and metatarsi. Leg formula: 1-4-2-3. Palps with retrolateral cymbial
apophysis, bulbus bag-like, embolus dagger-like (e.g., Figure 3A), sometimes furcate (Figure 5A). Tibial apophyses distinctive: ventral, retrolateral and dorsal – depending on species (Figure 3B). Epigyne with single oval hole, pocket-like depression (Figures 3G, 4C) or with anterior nose-like knob (Figure 5H). Insemination ducts long, forming hook-like loops, and accompanied by accessory glands (Figure 3H). Spermathecae round, their accessory glands – if visible – located at the entrance of insemination ducts. Fertilisation ducts short.

Relationships and biology
Simon (1909) included Adoxotoma within the Astieae (sensu Simon, 1901) – together with nine other genera. Petrunkevitch (1928) placed it within the Magoninae, without giving satisfactory justification. Wanless (1988) suggested the genus be excluded from the Astieae because of its different leg spination and cheliceral dentition. The latter character has been recognised as an important diagnostic and phylogenetic one since Simon (1901) published his monumental salticid classification. He considered the pluridentati state as the most primitive and the unidentati state as the most derived with the fissidentati being intermediate. However, the phylogenetic value of cheliceral teeth patterns in Salticidae has been contested (e.g., Prószyński, 1976) and cheliceral dentition is currently recognised as being of limited phylogenetic value, though still useful for identification in many cases.

The cheliceral dentition of Adoxotoma, being of intermediate fissi-pluridentati pattern, and not pluridentati as in other Astieae, seems not sufficient to exclude the genus from the group – as suggested by Wanless. The body form, leg structure and genitalia – especially in females – are definitely of Astieae-type. The epigynal depression/pocket, present in some Astieae, also occurs here, as well as oval spermathecae and long insemination ducts accompanied by accessory glands.

During the last two decades the problem of ‘primitive’ and ‘advanced’ Salticidae has also included behavioural studies but it is still far from being solved.

The relationships of Adoxotoma have recently become even more intriguing. While studying specimens collected in a forest survey in New South Wales (Zabka, unpublished data), I have found a number of unknown and very diverse genera. Some of them, especially females, have Adoxotoma-like genitalic pattern and similar leg structure (length and spination). A study of this material by D. Lugunov (Novosibirsk, Russia), some of which seems to be related to the genus Neon, should also help in clarifying Adoxotoma relationships.

All known species of Adoxotoma are either rainforest or wet sclerophyll forest dwellers, living on the ground, in leaf litter, under stones and rocks in cool and humid places. A. bargo has been observed to lay aggregations of several egg sacs under stones and rocks.

Distribution
Adoxotoma is known only from Australia. Of the five species studied, two are known from Western Australia and three from New South Wales, all from scattered localities.

For some species of Australian salticids, especially wet sclerophyll and rainforest inhabitants, scattered distributional patterns are quite common due to habitat partition and deforestation. In many cases, especially for leaf litter dwellers, the taxa that were thought to be rare and/or of limited range, appear widespread and more common when appropriate collecting methods are applied. However, despite extensive pitfall trapping – especially in the eastern part of the continent, still only limited materials of Adoxotoma have been found.

Adoxotoma nigroolivacea Simon, 1909
Map 1, Figure 1


Material Examined
Syntype
1$, Collie, Western Australia, Australia, 33°22'S, 116°09'E, 26 August 1905, W. Michaelsen, R. Hartmeyer (ZMB 17805).

Other Material
Australia: Western Australia: 1$, Fitzgerald

Map 1 Distribution of A. nigroolivacea (●) and A. bargo (○).
The salticid genus *Adoxotoma*

**Figure 1** *Adoxotoma nigroolivacea* Simon, 1909: A, epigyne; B, female internal genitalia; C, leg I; D, cheliceral dentition.

River National Park, Mt Maxwell, 34°12'S, 119°19'E, under rocks, 24 May 1994, M.S. Harvey, J.M. Waldock (WAM T41688); 1♀, Fitzgerald River National Park, St Mary River, 5 km inland, 34°10'S, 119°32'E, under rocks, 31 May 1994, M.S. Harvey, J.M. Waldock (WAM T41689); 1♀, Stephens Road, site 11 02, 03, 04, 06, 09, wet pitfalls, 32°44'03"S, 116°56'55"E, 30 October 1997–12 May 1998, P. Van Heurck, N. Guthrie (WAM T41693).

**Diagnosis**

Epigyne short and wide, spermathecae located anteriorly and copulatory openings oriented forwards.

**Description**

**Female** (syntype)

In poor condition, partly macerated with no original colours preserved. Cephalothorax orange-brown, darker in eye region. The latter also with scattered brownish hairs. Abdomen yellow-brown with scattered ambery hairs. Anterior spinnerets dark, others yellow-brown. Clypeus brownish. Chelicerae orange-brown, promargin and retromargin with 2 teeth (Figure 1D). Pedipalps orange-brown. Maxillae and labium pale orange-brown, chewing margins paler. Sternum yellowish-brown with darker margins. Legs I enlarged, orange-brown except for yellow tarsi, tibiae with 5 and metatarsi with 2 pairs of ventrolateral spines (Figure 1C). Other legs slightly lighter and more delicate.

Epigyne with 2 depressions divided by central ridge (Figure 1A). Insemination ducts wide, thick-walled. Spermathecae oval, translucent (Figure 1B).

**Female** (T41688)

In good condition, colours well preserved. Eye field grey brown, thorax smudged light brown, eye surrounding darker. Abdomen grey. Clypeus smudged orange brown, chelicerae ambery brown. Maxillae, labium and sternum ambery, the first with lighter inner margins. Venter greyish. Legs greyish brown, lighter posteriorly and dorso-ventrally. Other characters as in syntype described above.

Male unknown.

**Dimensions** (syntype)

CL 1.60, EFL 0.82, AEW 1.23, PEW 1.10, AW 1.35, AL 2.08.

**Distribution**

Recorded from several localities in south-west Western Australia (Map 1).

*Adoxotoma bargo* sp. nov.

**Material Examined**

Map 1, Figure 2

**Holotype**

♀, 17.5 km S of Pheasants Nest Br., near Bargo, New South Wales, Australia, W side of Hume Highway, 34°17'S, 150°35'E, wet sclerophyll forest, under rocks and stones, 24 October 1987, M. Zabka (AMS KS57664).

**Paratypes**

Australia: New South Wales, 5♀, 14 juv., same data (AMS KS57665).

**Diagnosis**

Epigyne with distinctive posterior depression.

**Description**

**Female** (holotype)

Cephalothorax dark brown. Abdomen shiny, greyish-dark brown with slightly lighter indistinctive chevrons. Hairs sparse. Spinnerets orange. Clypeus brown with lighter hairs and 3 brown protruding bristles. Chelicerae light brown with 2 promarginal and 4 retromarginal teeth, the latter forming fissidentati pattern (Figure 2D). Pedipalps orange dorso-ventrally, sides darker. Maxillae and sternum smudged brown, the former with orange chewing margins. Sternum brown, lighter centrally. Venter dark with indistinctive rows of lighter spots. Legs I (Figure 2C) light brown, distally lighter, tibiae with 5 and metatarsi with 2 pairs of ventrolateral spines, respectively. Other legs smudged orange.

Epigyne (Figures 2A, B) similar to *A. chinopogon*...
but with posterior depression instead of anterior pocket.

**Dimensions**
- CL 2.14, EFL 0.95, AEW 1.49, PEW 1.42, CW 1.67, AL 2.78.

**Distribution**
Known only from the type locality in New South Wales (Map 1).

**Etymology**
This species is named for the type locality.

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**Adoxotoma chinopogon** Simon, 1909

Map 2, Figure 3

**Material Examined**

**Syntypes**
- 1♀, Lion Mill [now Mt Helena], Western Australia, Australia, 31°53'S, 116°12'E, [date uncertain] (ZMH); 1♀, Wooroloo, Western Australia, stn 98, 31°48'S, 116°18'E, 29 May 1905, W. Michaelsen (MNHN).

**Other Material**
Australia: Western Australia: 2♀, 2♂, Fraser Range Stn, 150 m W of homestead, 32°04'S, 122°48'E, in sac together under granite, 22–23 April 1995, A.F. Longbottom (WAM 99/2372-5); 2♀, Fraser Range Stn, W of homestead, 32°04'S, 122°48'E, under granite slabs, A.F. Longbottom (WAM T41692); 2♀, Mt Cooke, near summit, 32°25'S, 116°18'E, 4 August 1990, M.S. Harvey, J.M. Waldock (WAM 93/1679-80); 1♀, base of Mt Cooke, 32°25'S, 116°18'E, 24 November 1990, M.S. Harvey (WAM 91/600); 2♀, Mt Cooke, 32°25'S, 116°18'E, hand collected, 31 July 1990.
Figure 3  Adoxotoma chinopogon Simon, 1909: A, B, male palp; C, male leg I; D, male cheliceral dentition; E, male maxilla; F, female leg I; G, epigyne; H, female internal genitalia; I, female cheliceral dentition; J, female general appearance.


Diagnosis
Palpal tibia with retrolateral and dorsal apophyses, epigyne with anterior pocket-like depression.

Description
Male (WAM 99/2372-5)
Thorax dark brown with scattered scale-like hairs, eye field almost black. Hairs few, whitish and brown. Abdomen with shiny black scutum, sides dark grey with lighter narrow stripes. Spinnerets smudged beige. Clypeus brown with pale long hairs overhanging towards chelicerae. Chelicerae light brown with 2 promarginal and 2–3 retromarginal teeth (Figure 3D). Maxillae with anterolateral
process (Figure 3E), smudged brown with lighter chewing margins. Labium and sternum smudged brown. Venter dark grey. Femora I brown with sides shining, proximal patellae and metatarsi and distal tibiae orange, the rest brown, tibiae with 5–6 pairs and metatarsi with 2 pairs of ventrolateral spines (Figure 3C). Other legs lighter and more slender. Ventral sides of coxae and trochanters II–IV contrasting light.

Palps as shown in Figures 3A, B. Femur with distal bump, tibiae with 2 apophyses, embolus dagger-like.

**Dimensions**

CL 1.71–1.89, EFL 0.75–0.82, AEW 1.10–1.21, PEW 1.03–1.14, CW 1.35–1.53, AL 1.78–1.94.

**Female (WAM 99/2372-5)**

Cephalothorax slightly lighter than in male, thoracic part with radial darker markings from fovea towards margins. Whole cephalothorax covered with sparse white and brown hairs. Abdomen dark grey with pattern of light spots, sometimes weakly marked. Brown hairs present anteriorly and grey marginally. Spinnerets smudged orange. Clypeus orange-brown with 3 central and single lateral orange bristles and sparse light hairs. Chelicerae smudged orange with 2 promarginal and 2 retromarginal teeth (Figure 3I), the latter fused at the base in fissidentati manner. Venter dark grey with lines of lighter spots. Patellae, tibiae and metatarsi I dark orange, other podomeres yellow-orange, tibiae with 5 anteroverentral and 4–5 posteroverentral spines (Figure 3F). Other legs yellow orange.

Epigyne (Figure 3G) with distinctive anterior pocket, accessory glands set approximately in the middle of insemination ducts (Figure 3H).

**Diagnosis**

Male palps with large ventral tibial apophysis, embolus not furcate, patella with small retrolateral outgrowth. Epigyne with anterior small oval depression. Copulatory openings wide apart, divided by broad central ridge, accessory glands in the proximal part of insemination ducts.

**Description**

**Male (holotype)**

Thorax dark brown with single white scale-like hairs. Eye field black. Abdomen with black shiny scutum and 2 median depressions (apodemes). Anterior spinnerets grey, median and posterior ones whitish. Clypeus dark brown with numerous white hairs overhanging towards chelicerae and with 3 brown bristles centrally. Chelicerae brown with 2 prolateral and 4 retrolateral teeth. Maxillae brown, with anterolateral outgrowth, labium brown, both with lighter chewing margins. Sternum smudged brown, lighter along median part. Venter grey, darkening laterally. Coxae, trochanters and proximal femora I orange, further parts of femora and patellae dark brown, tibiae and metatarsi smudged orange, tarsi yellow, tibia I with 6 and 5 proventral and retroventral spines, respectively.

**Dimensions**

CL 1.74–1.89, EFL 0.78–0.82, AEW 1.24–1.32, PEW 1.14–1.21, CW 1.35–1.46, AL 2.10–2.49.

**Distribution**

Known from south-west Western Australia (Map 2).

**Adoxotoma hannae** sp. nov.

**Material Examined**

**Holotype**

1♂, Murraramarang National Park, junction of Skid Ridge and North Head Rds, New South Wales, Australia, 35°41'09"S, 150°16'04"E, pitfall trap, 17 March 1999, L. Wilkie, R. Harris, H. Smith (AMS KS58764).

**Paratypes**


**Map 2** Distribution of *A. chimpogon* (●).
metatarsi with 2 pairs of spines. Legs II–III orange, IV – smudged orange.

Palps as shown in Figures 4A, B.

Dimensions

CL 2.35, EFL 0.99, AEW 1.53, PEW 1.32, CW 1.82, AL 2.39.

Female (paratype, AMS KS4588)


Epigyne (Figure 4C) relatively wide, with anterior oval depression, insemination ducts wide apart.

Map 3 Distribution of *A. hannae* (●).
Dimensions

CL 1.96, EFL 0.89, AEW 1.39, PEW 1.32, CW 1.49, AL 2.07.

Distribution

Known only from the type locality in New South Wales (Map 3).

Etymology

For my Mother Hanna.

Adoxotoma justyniae sp. nov.

Map 4, Figure 5

Material Examined

Holotype

1♀, Ramornie S[tate] F[orest], New South Wales, Australia, track off Mt Tindal Rd, 29°42'38"S, 152°38'09"E, pit fall trap, 18 February 1993, M. Gray, G. Cassis (AMS KS42279).

Paratypes

Australia: New South Wales: 1♀, Chaelundi S[tate] F[orest], 450 m, 1.2 km W along Stockyard Fire Trail from Chandlers Ck, 29°56'48"S, 152°31'46"E, pit fall trap, 18 February 1993, M. Gray, G. Cassis (AMS KS42806); 2♀, Chaelundi S[tate] F[orest], 450 m, 29°57'50"S, 152°31'23"E, 18 February 1993 (AMS KS42040); 1♀, Kanangra, Boyd National Park, Blood Filly Ck nr Jenolan Caves, 33°51'S, 150°03'E, 27 March 1976, M. Gray, G. Hunt, J. McDougall (AMS KS30006); 1♀, Currawong, 34°28'S, 148°22'E, 2 October 1966 (AMS KS19501); 1♀, Brindabella, Rules Point Road, 35°24'S, 148°45'E, wet sclerophyll forest, 1 April 1988, M. Zabka (AMS KS57666).

Diagnosis

Palps with hammer-like retralateral tibial apophysis, embolus furcate, epigyne with distinctive nose-like protruding knob.

Description

Male (holotype)

Eye field black, thorax dark brown with single white scale-like hairs. Abdomen rather short, with shiny black scutum and 2 distinctive depressions (apodemes) in the middle. Sides with longitudinal rows of blackish and light lines. Anterior spinnerets dark grey, median and posterior ones whitish. Clypeus dark brown, with 5 brown bristles (3 medially and single laterally), covered with many white hairs. Chelicerae orange-brown with 2 promarginal and 2 retromarginal teeth (Figure 5E). Maxillae and labium orange, sternum smudged light brown, venter blackish. Femora I brown, other podomeres lighter – especially near joints, tarsi yellow, tibiae with 5 pairs and metatarsi with 2 pairs of ventral spines. Other legs smudged orange with darker sides and lighter distal podomeres, tarsi yellow. Coxae and trochanters of legs II-IV contrasting light.

Palps (Figures 5A–D) massive, embolus furcate, tibia with 3 apophyses, the retralateral hammer-like.

Dimensions

CL 2.24, EFL 0.96, AEW 1.46, PEW 1.39, AW 1.71, AL 1.96.

Female (paratype, AMS KS30006)

Thorax brown with single scale-like hairs. Eye field darker, eye surrounding black. Abdomen shiny grey (Figure 5F). Hairs sparse, white and brown. Spinnerets orange. Clypeus brown with 5 brown bristles, 2 single laterally and 3 centrally and with long white hairs overhanging towards chelicerae. Chelicerae honey-orange, with 2 promarginal and 2 retromarginal teeth, the latter fused at the base in fissidentati-like manner. Maxillae and labium honey-smudged brown, chewing margins lighter. Sternum smudged orange with darker margin. Venter grey, darker laterally and posteriorly. Tarsi of legs I orange, other podomeres brown, tibiae with 5 pairs and metatarsi with 2 pairs of ventrolateral spines. Other legs orange-brown, lighter dorso-ventrally and distally. Coxae and trochanters of all legs contrasting light.

Epigyne (Figures 5H, I) very distinctive for its anterior nose-like knob.

Dimensions

CL 2.28, EFL 0.99, AEW 1.57, PEW 1.49, CW 1.71, AL 3.24.
The salticid genus *Adoxotoma*

**Distribution**

Known from several localities in New South Wales (Map 4).

**Etymology**

For Justynia, a friend of mine.

**ACKNOWLEDGEMENTS**

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REFERENCES


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Copepods from ground waters of Western Australia, V. 
*Phyllopodopsyllus wellsi* sp. nov. (Crustacea: Copepoda: Harpacticoida) with a key to world species

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Abstract – *Phyllopodopsyllus wellsi* sp. nov. is described from anchialine ground waters of the Cape Range karst area in north-western Australia and has clear stygomorphies, being colourless and lacking the nauplius eye. The genus is for the first time recorded from Australia, as well as for the first time from outside strictly marine habitats. A key to all the species of the genus *Phyllopodopsyllus* T. Scott, 1906 is presented.

INTRODUCTION

Arid north-western Australia is proving to contain a diverse stygofauna inhabiting both ancient freshwater systems (Bradbury and Williams, 1997; Poore and Humphreys, 1999a; Watts and Humphreys, in press) as well as anchialine waters (Humphreys, in press). Recently, a number of stygal cyclopoid copepods have been described from the ground waters of Western Australia in both near-coastal (Pesce et al., 1996a, 1996b; Pesce and De Laurentiis, 1996) and ancient continental regions (De Laurentiis et al., 1999). The present paper concerns an harpacticoid copepod from anchialine ground waters of north-western Australia, belonging to a genus previously recorded only in strictly marine habitats.

According to Bodin (1997), the tetragonicipitid genus *Phyllopodopsyllus* T. Scott, 1906 is, one of the most speciose marine harpacticoid genera, together with *Halectinosoma* Lang, 1944 and *Stenhelia* Boeck, 1865, and marine harpacticoid genus with the largest number of new described species in the last fifty years. Lang (1948) initially divided the genus *Phyllopodopsyllus* into two genera (*Phyllopodopsyllus* and *Paraphyllopodopsyllus*), based upon the shape of the second segment of the antennula and setation of second and third swimming legs in females. Many authors followed this revision, and Vervoort (1964) provided an useful key to species of the genus *Phyllopodopsyllus*, although not for *Paraphyllopodopsyllus*. After several new species were described possessing intermediate characteristics, Lang (1965) synonymized *Paraphyllopodopsyllus* with *Phyllopodopsyllus* and compiled an excellent key to 21 species them recognized. He subdivided the genus into three morphological groups based on the second antennular segment (i.e. presence or absence, and dimensions of an unguiform projection). Coull (1973) presented a very detailed survey of the genus *Phyllopodopsyllus*, and compiled an instructive table listing the most salient morphological characteristics. His key included 33 species and subspecies. Finally Kunz (1984) reviewed the genus, and tabulated setal formulae of the second, third, and fourth swimming legs in female, as well as the antennule segmentation and shape. He subdivided the genus into nine species groups, based on these characteristics: 1 - *bradyi*, 2 - *furciger*, 3 - *egypticus*, 4 - *boritzkyi*, 5 - *pauli*, 6 - *opistoceratus*, 7 - *mossmani*, 8 - *xenus*, and 9 - *longipalpalus* group. Fiers (1995) doubted the “naturalness of these groups”, but proposed nothing new, placing his new species (*P. yucatanensis*) within one of Kunz’s groups. Subsequent to the last review of the genus (Kunz, 1984) 13 new species and subspecies have been described: *P. alatus* Fiers, 1986; *P. crenulatus* Wells and Rao, 1987; *P. gracilipes* Wells and Rao, 1987; *P. stigmosus* Wells and Rao, 1987; *P. tenuis* Wells and Rao, 1987; *P. galapagoensis* Mielke, 1989; *P. kunzi* Mielke, 1989; *P. ancyclus* Mielke, 1992; *P. carinatus* Mielke, 1992; *P. mossmani chiloensis* Mielke, 1992; *P. hartmannorum* Kunz, 1995; *P. pallaresae* Kunz, 1995; and *P. yucatanensis* Fiers, 1995. In addition Wells and Rao (1987) described the male of *P. aegypticus* Nicholls, 1944 and Kunz (1995) described the male of *P. xenus* (Kunz, 1951). Kunz (1984) however did not mention three species already described: *P. laticauda* Por, 1964; *P. medius* Por, 1964; and *P. bahamensis* Geddes, 1968. Even though some of the species above are synonyms, the number of species in the genus *Phyllopodopsyllus* has increased considerably, and a key for their identification is therefore included in this paper. During an
investigation of the copepod fauna in Western Australia a new species of the genus *Phyllopodopsyllus* was identified. This new species is herein described as *P. wellsi* sp. nov.

**HABITAT AND ASSOCIATED FAUNA**

The copepods were sampled from ground water in karst terrain, accessed by temporary bores drilled for a seismic survey. The bores were located on a wave-cut limestone terrace overlain by Quaternary deposits on the north-western tip of the Cape Range peninsula, Western Australia. Bore A5 lies one kilometre south-east of Babjarrimannos at an altitude of a 12 m ASL and ca. 1000 m from the seashore; the water table approximates sea level and had a salinity of 24.7 g/dm³. Bore A7 is within one kilometre of Vlaming Head at an altitude of a 10 ASL and ca. 350 m from the seashore; the water is about sea level and had a salinity of 25.7 g/dm³. Ground water on the eastern side of the peninsula, where it has been recorded, typically tracks the marine tides but exhibits a temporal and amplitude lag (Humphreys et al., 1999). The waters are typically anchialine (Stock et al., 1986; Sket, 1996; Humphreys, 1999b) and exhibit a marked physico-chemical stratification (Humphreys, 1999b). Fauna sampled within the same bores as *Phyllopodopsyllus wellsi* sp. nov. were all stygal species and included the blind gudgeon *Milyeriuga veritas* Whitley (Pisces: Eleotridae), calanoid copepods and melitid amphipods. These form part of a more widespread and diverse stygofauna inhabiting both fresh and anchialine waters of the Cape Range peninsula, with elements being found on Barrow Island 170 km to the north-east (Humphreys, 1999b; in press; Humphreys et al., 1999). The following cyclopoid copepods are known from the area: *Apocyclops detigizicus* (Lepechkine), *Halicyclops longifurcatiis* Pesce, De Laurentiis and Humphreys, *Metacyclops mortoni* Pesce, De Laurentiis and Humphreys, *Microcyclops varicans* G.O. Sars, and *Diacyclops humphreysi* Pesce and De Laurentiis. In addition, the wider anchialine fauna contains numerous widely disjunct taxa, many of which occupy a "Tethyan" track, such as *Lasinectes* (Remipedia), *Halosbaena* (Thermosbaenacea), *Haptolana* (Isopoda), *Liagoceradocus* (Amphipoda), *Danielopolitm* (Ostracoda), as well as misophrioid and calanoid copepods (Yager and Humphreys, 1996; Poore and Humphreys, 1992; Bruce and Humphreys, 1993; Bradbury and Williams, 1996; Danielopol et al., in press).

**MATERIAL AND METHODS**

The sites were sampled using baited traps and haul-nets from 'uphole' bores drilled to locate recording equipment for a seismic survey. Permanent mounts were made in commercial polyvinyl-lactophenol and in Faure's medium. Dissected specimens were drawn at magnification of 630x and 1000x with drawing tube mounted on a Leica DMLS microscope, with C-plan achromatic objectives. All material is deposited in the Western Australian Museum (WAM) and BES denotes field numbers from the Invertebrate Biogeography and Ecology group. Abbreviations used in the key to species are: Fu – furcal rami; A1 – antennula; P1-P4 – first to fourth swimming leg; P5 – fifth leg; Enp – endopodite; Exp – exopodite; Enp2P3 – second endopodite segment of the third swimming leg.

**SYSTEMATICS**

*Family Tetragonicipitidae Lang, 1944*

*Genus Phyllopodopsyllus* T. Scott, 1906

*Phyllopodopsyllus wellsi* sp. nov. Figures 1-19

**Material Examined**

**Holotype** ♀ (WAM C24456), Cape Range, AB7, Western Australia, Australia, 21°49'S, 114°06'E, 11 November 1995, leg. R.D. Brooks (BES 4676.1).

**Allotype** ♀ (WAM C244457), Cape Range, AB7, Western Australia, Australia, 21°49'S, 114°06'E, 11 November 1995, leg. R.D. Brooks (BES 4676.1).

**Para types** Australia: Western Australia: 14 ♀, 11 ♂ (9 ovigerous) (WAM C24458 - C24465, on slides, C24466 in alcohol) Cape Range, AB7, 21°49'S, 114°06'E, 11 November 1995, leg. R.D. Brooks (BES 4676.2).

**Other material** Australia: Western Australia: 3 ♂, 5 ♀ (4 ovigerous) (WAM C24467, in alcohol), Cape Range, AB7, 21°49'S, 114°06'E, 5 November 1995, leg. R.D. Brooks (BES 4673).

♀ (WAM C24468, on slide), Cape Range, AB5, 21°50'S, 114°05'E, 4 November 1995, leg. R.D. Brooks (BES 4666).

**Description**

Female (holotype)

Habitus elongated, cylindrical. Body colourless, and nauplius eye absent. Cuticle densely furnished with minute pits, especially on furcal rami and antennula (Figures 1 and 2). Prosome comprising cephalothorax, incorporating first pedigerous
Phyllopodopsyllus wellsi sp. nov. from ground waters of Western Australia

Figures 1-4  Phyllopodopsyllus wellsi sp. nov., holotype (female): 1 – antennula and rostrum; 2 – abdomen, dorsal view; 3 – maxilliped; 4 – mandibula. Scales = 0.1 mm.
somite, and 3 free pedigerous somites. Surface of dorsal shield covering cephalothorax with many sensillae, as well as tergites of 3 free pedigerous somites. Hind margins of somites smooth. Rostrum almost quadrate, with single pair of sensillae, and with row of very fine spinules on distal margin (Figure 1). Urosome comprising fifth pedigerous somite, genital double-somite (representing fused genital and first abdominal somite), and 3 free abdominal somites. Surface of with row of very fine spinules on distal margin almost quadrate, with single pair of sensillae, and somites. Hind margins of somites smooth. Rostrum sonute, genital double-somite (representing fused genital and first abdominal somite), and 3 free (Figure 1). Urosome comprising fifth pedigerous visible dorsally, furnished with 6 sensillae, while laterally and ventrally marked by rigid internal somite, as well as on first free abdominal somite (Figure 2); second free abdominal somite lacking sensillae. Their hind margins smooth, too. Anal somite (last abdominal somite) ornamented only with pair of sensillae dorsally. Anal operculum convex, not reaching beyond limit of anal somite, with many marginal spines (Figure 2).

Furcal rami divergent, about 3.8 times longer than wide, with complete armature (2 lateral, 1 dorsal and 3 apical setae), and without dorsal chitinous ridge. Their inner margins with row of fine hairs, especially long in distal part (Figure 2). Dorsal seta attached at distal sixth of furcal length, well developed, while lateral setae very short. Outer apical seta somewhat moved to ventral side, as long as inner apical seta. Middle apical seta extraordinary strong, slightly curved at end, and long as other two apical setae.

Antennula 8-segmented, with 1 slender aesthetasc on apical segment,1 very long aesthetasc on fourth segment (more than twice longer than 4 distal segments taken together), and with setal formula as follows: 1.8.5.2.1.2.4.7 (Figure 1). All setae smooth. Second segment with very large, posteriorly directed, unguiform process, and lacking anterior process. First segment about 3 times as long as wide.

Antenna with almost completely reduced coxa, 1-segmented basis and exopodite, and 2-segmented endopodite (Figure 12). Inner margin of basis furnished with long spinules. Exopodite with 3 elements, of which outer one basally fused with segment. First endopodite segment only with few small spinules on outer margin. Second endopodite segment with 2 lateral spines and 6 apical setae, as well as with many spinules along outer margin (Figure 12).

Mandibula with cutting edge of coxa with row of teeth of different thickness and with single lateral seta (Figure 4). Basis large, bearing 3 setae on inner margin (1 smooth and 2 plumose), and furnished with 2 transverse rows of long slender spinules. Endopodite twice longer than exopodite, armed with 2 lateral and 4 apical smooth setae. Exopodite armed with 1 lateral and 2 apical (1 smooth and 1 plumose) setae (Figure 4). Both rami 1-segmented. Maxillula with 13 setae on precoxa, 5 setae on coxa, 8 on basis, 4 on endopodite and 3 setae on exopodite.

Maxilla with 10 seta on syncoxa (2 setae on each of proximal 2 endites; 3 setae on each of distal 2 endites), 4 on basis and 6 setae altogether on 2-segmented endopodite.

Maxilliped with unornamented syncoxa, which armed with 3 plumose setae (Figure 3). Basis with 1 seta and row of long spinules on inner margin. Endopodite 1-segmented, armed with strong recurved apical claw and slender smooth subapical seta (Figure 3).

All swimming legs with 3-segmented exopodites and 2-segmented endopodites (Figures 5, 7, 8 and 11). Spine and setal formula on exopodites and endopodites from first to fourth swimming legs (legend: inner / outer spine or seta; inner / terminal / outer):

<table>
<thead>
<tr>
<th>Segments</th>
<th>Exopodite</th>
<th>Endopodite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0/1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>0/0</td>
<td>0/1</td>
</tr>
<tr>
<td>Fourth leg</td>
<td>0/1</td>
<td>0/2/0</td>
</tr>
</tbody>
</table>

Couplers (intercoxal sclerites) of all swimming legs with concave distal margin and without surface ornamentation. Coxa of third and fourth swimming legs unornamented, while coxa of second leg bearing row of hairs on inner-distal corner and coxa of first leg ornamented with row of spinules on outer margin. Basis of first and second swimming legs with row of hairs on inner margin, while those of third and fourth legs without ornamentation. Basis of first swimming leg bearing 1 strong spine on inner margin (attached at first third of segment's length). All swimming legs with smooth epipodite setae, on outer margin of basis. Apical and outer elements on distal exopodite segment of fourth swimming leg reduced, setiform (Figure 5).

Fifth leg typically foliaceous, with completely fused basoendopodite and exopodite, but with clear chitinous suture marking original separation (Figure 13). Epipodite seta well developed, and between it and proximal margin of basis 1 row of slender spinules exists. Former basoendopodite armed with 4 slender setae. Former exopodite segment armed with 6 setae, of which only innermost one plumose. Fifth seta on that segment, from inner margin, characteristically curved (Figure 13). Fifth leg cavity without eggs.

Sixth leg fused with genital double-somite, bearing 2 smooth setae, of which outer one about 1.8 times longer than inner (Figure 6). Genital field present in distal half of first genital somite, having short copulatory ductus connecting wide copulatory pore and small paired seminal
Phyllopodopsyllus wellsi sp. nov. from ground waters of Western Australia

Figures 5-9  Phyllopodopsyllus wellsi sp. nov., holotype (female): 5 - fourth swimming leg; 6 - genital double-somite, ventral view; 7 - second swimming leg; 8 - third swimming leg; 9 - genital double-somite, dorsal view. Scales = 0.1 mm.
Figures 10–13 *Phyllopodopsyllus ivalhi* sp. nov.; 10, allotype (male); 11–13, holotype (female): 10 – abdomen, lateral view; 11 – first swimming leg; 12 – antenna; 13 – fifth leg. Scales = 0.1 mm.
Figures 14–19  *Phyllopodopsyllus wellsi* sp. nov., allotype (male): 14 – antennula and rostrum; 15 – third swimming leg; 16 – fourth swimming leg; 17 – second swimming leg; 18 – fifth leg; 19 – genital somite with sixth leg, lateral view. Scales = 0.1 mm.
receptacles. Small, tongue-like, spermatophore attached to genital pore (Figure 6).

**Male (allotype)**

Body similar to female in general appearance, slightly more slender. Urosome comprising fifth pedigerous somite, genital somite, and 4 free abdominal somites. Genital somite about 1.5 times broader than long. All somites with smooth hind margins, and with different number of sensillae.

Furcal rami similar to female, but outer and middle apical setae much longer (Figure 10). Outer apical seta more than twice longer than inner apical one, while middle apical seta almost as long as abdomen.

Antennula strongly geniculate, with almost completely fused fourth and fifth segments (only 1 cuticular suture remained between them), and with completely fused sixth and seventh segments (Figure 14). First and second, as well as ultimate, segments very similar to female.

Antenna, mandibula, maxillula, maxilla, maxilliped, first swimming leg, exopodite of second (Figure 17) and third swimming legs (Figure 15) also very similar to those of female.

Outermost apical seta on distal endopodite segment of second swimming leg very strong and basally fused with segment (Figure 17). Innermost apical seta on that segment short and smooth. Endopodite of fourth swimming leg similar to female, except for inner apical seta on distal segment being much stronger, curved, and smooth (Figure 16). Distal endopodite segment of fourth swimming leg with only 5 appendages (2 inner, 1 apical and 2 outer).

Basoendopodite of fifth leg with 3 strong, plumose and spiniform endopodite setae (innermost seta longest), and with very long and smooth epipodite seta (Figure 18). Exopodite subquadrangular, somewhat longer than broad, and armed with 5 elements (of which innermost spine extraordinary strong and longest). Outer-distal corner of exopodite distinctly produced, but without sharp extension.

Sixth leg consisting of small triangular chitinous plate bearing 3 setae (Figure 19). Middle seta about 1.6 times longer than inner one, and 2.8 times longer than outermost seta.

**Variability**

Thirty-six specimens (18 males and 18 females) of *Phyllopodopsyllus wellsi* sp. nov., from 3 different localities, were found and examined. Eleven specimens were completely dissected and mounted on slides. Body length, measured from the tip of rostrum to the posterior margin of furcal rami, ranges from 0.41 mm to 0.523 mm (0.455 mm average) in males, and from 0.47 mm to 0.592 mm (0.527 mm average) in females. In both sexes the distal endopodite segment of the third swimming leg can have either 2 or 3 apical setae. In specimens with 3 setae, the pattern is very similar to that of the distal endopodite segment of the second swimming leg in females (Figure 7). Sometimes left and right third legs of the same specimen can bear different number of setae on that segment. No such variability has been noted in the number of setae and spines of the other swimming legs. The exopodite of the male fifth leg with or without very small sharp extension on outer-distal corner (between second and third setae, from outer side). Moreover, sometimes one leg displays such extension, while opposite leg does not in same animal. The outer seta on the female sixth leg can be more or less plumose. Anal somite in female usually with 1 row of very small, equal, spinules at base of furcal rami ventrally, but sometimes with a few larger spinules in the middle of that row. Holotype female is without eggs, but ovigerous females always with only two large eggs in the fifth leg cavity. The eggs are with very thin chorion.

**Etymology**

The species is named in honour of Dr J.B.J. Wells, Victoria University of Wellington, New Zealand.

**DISCUSSION**

*Phyllopodopsyllus wellsi* sp. nov. differs from all other species in the genus by its characteristic furcal rami shape in the female, and especially by the middle apical seta, which is very short, stout, and slightly and characteristically curved distally. Basoendopodite of the fifth leg in male with innermost seta the longest is also a rare characteristic in the genus *Phyllopodopsyllus*. Only three other species possess a similar basoendopodite: *P. xenus* (Kunz, 1951); *P. paraxeniis* Coull, 1970; and *P. hennani* Coull, 1969. *P. xenus* has indeed only two setae on that segment (Kunz, 1995), and differs from the new species also by many other characters such as antennula segmentation, swimming legs setation, furcal rami shape, etc. *P. paraxeniis* has 9-segmented antennula without unguiform process on second segment, possesses different setation of swimming legs, and a different furcal rami shape (Coull, 1970). Also, the middle seta on fifth leg basoendopodite in male of that species is extremely short. *P. hennani* differs from the new species by many characteristics (Coull, 1969). Regarding the shape of the fourth swimming leg endopodite in female (1 seta on basal and 2 setae on distal segment) *P. wellsi* is similar with the four following species: *P. minutus* Lang, 1948; *P. bahamensis* Cedeño, 1968; *P. paraxeniis* Coull, 1970; and *P. tenuis* Wells and Rao, 1987. They all differ from the new species by their swimming leg setation and shape of the furcal rami, whereas *P. bahamensis* and *P. paraxeniis* also differ by the
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antennula segmentation (Lang, 1948; Geddes, 1968; Coull, 1970; Wells and Rao, 1987). *P. wellsi* does not fit well within any of nine species group created by Kunz (1984), which maybe confirms suspicions about its naturalness expressed by Fiers (1995), but the philogenetical grouping of the species is outside the scope of this paper. Because we do not want to create a new group for this species, we provide a key to all species and subspecies in the genus *Phyllopodopsyllus*. In that key have used mainly female morphological characteristics, unless stated otherwise.

**Key to species and subspecies of the genus Phyllopodopsyllus**

1. EnpP4 1-segmented ....................................... 2
   EnpP4 2-segmented ....................................... 3
2. Enp1P2 and Enp1P3 with inner seta .......................... *P. geddesi* Kunz, 1984
   Enp1P2 and Enp1P3 unarmed ................................ *P. opisthoceratus* Geddes, 1968
3. Enp1P4 unarmed ........................................... 4
   Enp1P4 with inner seta .................................... 8
4. A1 9-segmented ........................................... *P. xenus* (Kunz, 1951)
   A1 8-segmented ........................................... 5
5. Exp1P 2-segmented ....................................... *P. biarticulatus* (Wells, 1967)
   Exp1P 3-segmented ....................................... 6
6. Enp2P4 with 3 setae ...................................... *P. longipalpatus hawaliensis* Kunz, 1984
   Enp2P4 with 2 setae ...................................... 7
7. Fu with dorso-lateral cuticular process ...................... *P. longipalpatus madagascarensis* Kunz, 1984
   Fu without that process .................................. *P. longipalpatus longipalpatus* (Chappuis, 1954)
8. Enp2P4 with only 1 seta .................................. *P. hermani* Coull, 1969
   Enp2P4 with more than 1 seta ........................... 9
9. Enp2P4 with 2 setae ..................................... 10
   Enp2P4 with 3 setae ..................................... 14
10. A1 9-segmented ......................................... 11
    A1 8-segmented ......................................... 12
    A1 without unguiform process ............................ *P. paraxenus* Coull, 1970
12. Enp1P3 without seta .................................... *P. minutus* Lang, 1948
    Enp1P3 with inner seta ................................ 13
    Exp3P2 and Exp3P3 with 5 setae/spines ................ *P. wellsi* n.sp.
14. Enp1P3 without seta .................................... 15
    Enp1P3 with inner seta ................................ 21
15. Exp2P4 without inner seta ................................ *P. mediatus* Por, 1964
    Exp2P4 with inner seta ................................ 16
16. Enp2P2 and Enp2P3 with 2 setae .......................... *P. hartmannorum* Kunz, 1995
    Enp2P2 and Enp2P3 with 3 setae ........................ 17
17. Enp1P1 without inner seta ................................ *P. punctatus* Kitazima, 1981
    Enp1P1 with inner seta ................................ 18
18. Exp3P2 with 4 setae/spines ................................ *P. laticauda* Por, 1964
    Exp3P2 with 5 setae/spines ................................ 19
19. A1 8-segmented .......................................... *P. bermudaec* Lang, 1948
    A1 9-segmented .......................................... 20
20. Enp1P1 almost as long as Exp1P ........................ *P. angolensis* Kunz, 1984
    Enp1P1 about 1.5 times longer than Exp1P ............ *P. agypticus* Nicholls, 1944
21. Enp2P2 without seta .................................... 22
    Enp2P2 with inner seta .................................. 23
22. Exp2P4 without inner seta ................................ 23
    Exp2P4 with inner seta .................................. 24
    A1 8-segmented .......................................... *P. simplex* Kitazima, 1981
24. Exp3P3 with 5 setae/spines ................................ *P. langi* Kunz, 1975
    Exp3P3 with 6 setae/spines ................................ 25
25. A1 9-segmented .......................................... 26
    A1 8-segmented .......................................... 28
26. Fu about 7 times as long as wide ........................ *P. longicaudatus* A. Scott, 1909
    Fu less than 2.5 times as long as wide ............... 27
27. Fu with large proximal inner bulge ....................... *P. bradyi* (T. Scott, 1892)
    Fu without proximal inner bulge ....................... *P. pallaresae* Kunz, 1995
28. A1 with additional sharp process on the anterior distal corner of second segment .... 29
    A1 without additional sharp process (just one unguiform, posteriorly directed) .......... 30
29. Dorsal seta attached almost at end of Fu ........................ *P. parafurciger parafurciger* Geddes, 1968
    Dorsal seta attached at 2/3 of furcal length ........ *P. parafurciger caroliensis* Coull, 1971
30. Fu with well developed dorsal chitinous ridge. ........................................... P. furciger Sars, 1907
31. Fu without dorsal ridge ................................................................. 31
32. Exp2P4 without inner seta .............................................................. 33
33. A1 8-segmented .............................................................................. 34
34. Exp3P3 with 4 setae ................................................................. P. danielae Bodin, 1964
35. A1 without or with small blunt process ........................................ 37
36. Exp3P4 with 6 setae and spines ........................................................ P. paraborutzkyi Kunz, 1975
37. A1 with small blunt process on second segment .......................... 38
38. Exp3P4 with 6 setae and spines, Fu 1.5 times longer than wide .......... P. hibernicus (Roe, 1955)
39. Exp3P4 with 7 setae and spines ...................................................... P. paramossmani (Lang, 1934)
40. Fu about 3.5 times as long as broad .............................................. P. berriei Monard, 1936
41. Middle apical seta on Fu not broadened basally ......................... P. laspalmeiis Marinov, 1973
42. Exp3P4 with 5 setae ................................................................. P. mossmani T. Scott, 1912
43. A1 8-segmented .............................................................................. 44
44. Exp3P2 and Exp3P3 with 4 setae/spines ........................................... P. mossmani chiloensis Mielke, 1992
45. Middle apical seta on Fu minute compared to furcal length .......... P. pauli Crisafi, 1960
46. Exp3P4 with 6 setae/spines ................................................................. P. ancylus Mielke, 1992
47. Exp3P3 with 5 setae/spines ................................................................. P. chawi Coull, 1970
48. Exp3P3 with 6 setae/spines ................................................................. P. galapagoensis Mielke, 1989
49. A1 with unguiform process on second segment ......................... P. parabradyi Lang, 1965
50. Abdominal somites with spiniform cuticular extensions ................. P. alatus Fiers, 1986
51. A1 without such process ................................................................. 49
52. A1 without any process ................................................................. 39
53. Exp3P3 with 5 setae/spines ................................................................. P. setouchiensis Kitazima, 1981
54. Exp3P4 with 7 setae/spines ................................................................. P. setouchiensis Kitazima, 1981
55. A1 9-segmented .............................................................................. 47
56. Exp3P2 with 5, while Exp3P3 with 6 setae/spines .......................... 46
57. A1 without process ................................................................. 42
58. EnplPl about as long as ExpPl .............................................................. P. briani briani Petkovski, 1955

Large harpacticoid genera frequently accumulate numerous synonyms during the course of their
taxonomic history. The genus Phyllopodopsyllus is especially rich with synonyms, many known of long
standing. In such a way P. pirgos Apostolov, 1969 is a synonym of P. briani Petkovski, 1955, what was
noticed by Coull (1973) and accepted by Apostolov and Marinov (1988), although Kunz (1984) claimed
it to be a synonym of P. thiebaudi Petkovski, 1955.
Two species were synonymized by their authors themselves: Kunz (1963) synonymized his P.
trichophorus (Kunz, 1951) with P. mossmani T. Scott, 1912; and Apostolov (1972) synonymized his P.
californicus Kunz (1984) are synonyms of P. setouchiensis Kitazima, 1981, which was nicely
noticed by Mielke (1992), but also P. crenulatus Wells and Rao, 1987 is a synonym of P. setouchiensis.
Although Wells and Rao (1987) said that P. crenulatus "is unique in no single character but the
combination is not matched by any other species of
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the genus”, furcal rami shape, setal formula, antennae, and many other characteristics are quite the same as in P. setouchiensis. P. gertrudi Kunz, 1984 and P. gertrudi costaricensis Mielke, 1992 are synonyms of P. aegypticus Nicholls, 1944. As a result of the description of P. g. costaricensis, Mielke (1992) unintentionally returned the nominal species P. gertrudi within the range of the species P. aegypticus, because the only traditionally used differentiating character (i.e. distal exopodite segment of third swimming leg with 5 or 6 elements) become invalid. Both species have, among other characters, quite the same extraordinary strong spines on the distal endopodite segments of second and third swimming legs (see Kunz, 1984; Wells and Rao, 1987; and Mielke, 1992). P. yucatanensis Fiers, 1995 is an obvious synonym of P. parafurciger Geddes, 1968, and it is very strange how Fiers (1995) tried to make differential diagnosis of his species on the base of the relative length of some setae. Several species are included in the key, because we could not claim with the great certainty that they are synonyms. Thus, the differential character (furcal length/width ratio) between P. curtus Marcus, 1976 and P. stigmosus Wells and Rao, 1987 applied in our key should be used with caution since the variability of the first species is unknown. Although Marcus (1976) mentioned that the furcal index is 9, from the drawings that she provided it appears that the ratio is not higher than 6.4. P. carinatus Mielke, 1992 is very similar to P. parabrotzsky Kunz, 1975, but the variability of the latter is practically unknown (Kunz, 1975). The same applies to P. galapagoensis Mielke, 1989 and P. chavei Coull, 1970 (see Mielke, 1989; Coull, 1970). P. petkovskii Kunz, 1984 is so similar to P. briani Petkovski, 1955 that, since their populations are located on two completely opposite parts of the world, the former can be at most considered as a subspecies of P. briani, and so has been treated in our key as P. briani petkovskii Kunz, 1984 stat. nov.). Two species are not included in the key although they clearly belong to the genus Phyllopodopsyllus: P. minor (T. and A. Scott, 1903) and P. tristanensis (Wiborg, 1964). These two species are considered incertae sedis, because of the incompleteness of their descriptions. Lang (1965) and Coull (1973) included P. minor in their keys on the basis of the furcal rami shape, but today this is impossible.

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chemical profile of Bundera Sinkhole, an anchialine remiped habitat at Cape Range, Western Australia. Journal of the Royal Society of Western Australia 82: 99–108.


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Notes on the spider genus *Symphytognatha* (Araneae: Symphytognathidae) in Western Australia

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Abstract – New distributional records are given for *Symphytognatha picta* Harvey, and a new species, *S. fouldsi*, is described from a cave situated in Nambung National Park.

INTRODUCTION

The symphytognathid fauna of Australia has been little studied, with only five described species: *Symphytognatha globosa* Hickman, 1931 from Tasmania, *S. blesti* Forster and Platnick, 1977 from New South Wales, *Anapistula australia* Forster, 1959 from Queensland, *S. picta* Harvey, 1992 and *A. troglobia* Harvey, 1998 from Western Australia, and *A. bifurcata* Harvey, 1998 from Northern Territory (see Forster and Platnick, 1977; Harvey, 1992, 1998). Amongst material recently accessioned by the Western Australian Museum were two specimens of *Symphytognatha* taken from a cave some 180 km to the north of Perth which were clearly different in morphology from *S. picta*, the only other species of the genus recorded from Western Australia. Detailed examination of the specimens shows that it represents a distinct species most similar to *S. blesti* from New South Wales.

The specimens examined as part of this study are lodged in the Western Australian Museum (WAM). The terminology used for the pedipalpal conductor lobes follows Harvey (1992).

SYSTEMATICS

Family Symphytognathidae

Genus *Symphytognatha* Hickman

*Symphytognatha picta* Harvey

*Figure 3*

*Symphytognatha picta* Harvey, 1992: 685–689, figures 1–6.

New Material Examined

Australia: Western Australia: 1 ♂, Dog Pool, Shannon National Park, 34°46'S, 116°22'E, 23 March 1993, sweeping vegetation, M.S. Harvey, J.M. Waldock (WAM 97/2560); 1 ♂, Jarrahdale, minesite, 32°17'S, 116°08'E, April 1998, suction sample, K.E.C. Brennan (WAM T41515); 1 ♂, same data except pitfall trap (WAM T41516); 1 ♀, same locality, April 1999, suction sample, B. Moir (WAM T41517); 1 ♀, S. of Torbay Hill, West Cape Howe National Park, 35°05'S, 117°38'E, 27 March 1993, sweeping vegetation, M.S. Harvey, J.M. Waldock (WAM 97/2561).

Remarks

The distribution of *S. picta* extends along the south coast of Western Australia (Figure 3) where the high rainfall favours the retention of moisture dependent species (Hopper et al., 1996), but an outlying population has been recently found near Jarrahdale by Mr Karl E.C. Brennan (Curtin University of Technology). This disjunction is very similar to that of the south-western Australian endemic *Ambicodamus marae* Harvey (Nicodamidae), which was found by Brennan (1999) to be prevalent along the south coast with outlying populations situated in the northern jarrah forest at Jarrahdale and Mt Cooke. The habitat and collecting methods of the Jarrahdale site were described by Brennan (1999).

*Symphytognatha fouldsi* sp. nov.

*Figures 1–3*

Material Examined

Holotype

♂, Thousandman Cave, SH-7, Nambung National Park, Western Australia, Australia, 30°30'S, 115°10'E, 27 September 1998, from web on roof ledge, R. Foulds (WAM T40852).

Paratype

Australia: Western Australia: 1 ♂, same data as holotype, except from web strand over runnel, edge of daylight zone (WAM T40853).
Figures 1–2 *Symphytognatha fouldsi* sp. nov., holotype m, left pedipalp: 1, retrolateral; 2, detail of embolus and conductor lobes. Abbreviations: C1 (ventral conductor lobe), C2 (dorsal conductor lobe).

**Diagnosis**

Males of *S. fouldsi* appear to be most similar to those of *S. blesti* as both possess a long embolus which extends well past the conductor lobes and which is furnished with an expanded tip. However, in *S. fouldsi* the ventral edge of C1 is rounded and does not form a 90° angle at the tip (it is straight and forms a 90° angle in *S. blesti*), and the dorsal edge of C2 is rounded (it forms a sharp point in *S. blesti*).

**Description**

**Male**

Colour: carapace dark dusky brown, pars cephalica darkest; sternum dark brown; abdomen mostly purple-grey with broad irregular median pale stripe and irregular lateral pale stripes directed ventrally; chelicerae and legs light brown. Carapace with 10 long setae, 1 on clypeus, 1 between PME, 1 pair mesad to ALE, 1 pair mesad to PLE, and 4 on posterior ridge of pars cephalica; clypeus slightly oblique. Six eyes, AME absent, grouped in three diads. Chelicerae fused for most of their length, suture line visible; each chelicera with 6 lateral, 2 mesal and 2 distal setae; distal lobe of fang furrow with 2 large teeth and 1 small tooth. Sternum posteriorly truncate. Pedipalp (Figures 1–2): trochanter with small subdistal seta, femur and patella without setae, tibia with 2 large and 1 small subdistal setae; subbasal paracymbium present with 3 large setae and deep dorsal notch; outer margin of cymbium with 5 lateral and 2 subdistal plumose setae which extend over bulb; embolus long, extending past conductor lobes, tip expanded with distal flange, situated between two conductor lobes; ventral conductor lobe (C1) with rounded distal and ventral margins; dorsal conductor lobe (C2) not hooked. Leg formula 4123; all patellae and tibiae with dorsal erect bristle. Superior tarsal claws: I and II with 7–8 teeth, III and IV without accessory teeth; inferior tarsal claws I–IV long and slender. Colulus absent.

Dimensions (mm), m holotype: total length (excluding chelicerae) 1.16. Carapace length 0.44, width 0.40, height 0.31. Eyes: ALE 0.06, PME 0.04, PLE 0.06, PME-PME 0.02, PME-PLE 0.09, PLE-ALE 0.01, eye group width 0.32. Sternum length 0.29,
width 0.22. Abdomen length 0.81, width 0.71, height 0.82. Pedipalp: femur 0.10, patella 0.07, tibia 0.13, tarsus 0.20, total 0.50. Leg I: femur 0.32, patella 0.15, tibia 0.19, metatarsus 0.17, tarsus 0.13, total 0.96. Leg II: femur 0.31, patella 0.13, tibia 0.20, metatarsus 0.15, tarsus 0.20, total 0.99. Leg III: femur 0.22, patella 0.15, tibia 0.17, metatarsus 0.12, tarsus 0.17, total 0.83. Leg IV: femur 0.32, patella 0.14, tibia 0.21, metatarsus 0.16, tarsus 0.21, total 1.04.

Remarks
All three previously described Australian species of *Symphytognatha* possess a distinct abdominal colour pattern which consists of a dark background with dorsal and lateral pale stripes (Harvey, 1992), and *S. fouldsi* fits into that group. *Symphytognatha fouldsi* shares considerable similarities with *S. blesti* from New South Wales, as males of both species possess a long embolus with an expanded tip (see Forster and Platnick, 1977), and they differ only by the shape of the conductor lobes.

The two known specimens of *S. fouldsi* were taken from Thousandman Cave, situated in Nambung National Park, although there is little to suggest that the species are restricted to caves, as they possess fully developed eyes and are not appreciably paler than other species of the genus.

Etymology
This species is named for the collector of the two specimens, Mr Rob Foulds, who has provided the Western Australian Museum with many important invertebrates from Western Australian caves.

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The green swordtail *Xiphophorus helleri* Heckel (Poeciliidae): another aquarium fish established in the wild in Western Australia

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INTRODUCTION

Considering the enormous number of fish imported into Western Australia each year by the aquarium trade (ca. 600,000 individual fish/year from overseas destinations – this figure does not include fish imported from elsewhere in Australia) (W. Cross, personal communication – Australian Quarantine and Inspection Service), it is fortunate that very few species have established wild populations here. Although only a small number of introduced aquarium species, such as tilapia *Oreochromis mossambicus* (Cichlidae), goldfish *Carassius auratus* (Cyprinidae), carp *Cyprinus carpio* (Cyprinidae), one-spot livebearers *Phalloceros caudimaculatus* (Poeciliidae) and the mosquitofish *Gambusia holbrooki* (Poeciliidae) are presently entrenched in Western Australian inland waters (Trendall and Johnson, 1981; Allen, 1989; Pen and Potter, 1991; Morgan *et al.*, 1998; Kailola *et al.*, 1999; WA Museum Records; unpublished data), the sheer numbers of these and other species entering the state guarantee an uncertain future. The species mentioned above have either been deliberately or accidentally released into various waterbodies throughout the state and, as this paper highlights, it is probably only a matter of time before other non-native species establish self-maintaining populations in Western Australia.

Many introduced species not only compete with native fish for food and habitat, but may also exhibit agonistic behaviour towards or prey on native fish, often displacing them from their preferred habitat or even replacing them in entire systems (e.g. Arthington and Lloyd, 1989; Hutchinson, 1991; Gill *et al.*, 1999; Kailola *et al.*, 1999). Although Western Australia has some of the strictest quarantine laws in the country with regard to most imports, incoming aquarium fish, particularly those entering via eastern Australia, are subjected to only limited checks, thereby increasing the risk of introducing noxious species and/or diseases or parasites that may be harboured either in or on the fish or in the water in which they are transported.

While the green swordtail *Xiphophorus helleri* (Poeciliidae) (Figure 1) has long been imported into Australia for use in the aquarium trade, a self-maintaining population has not previously been captured in the natural waterways of Western Australia. Feral populations of this species have, however, been found in some drainages in Queensland since the 1960’s as well as in New South Wales, the Northern Territory and also in the drainages of Lake Eyre (McKay, 1978; Thompson, 1982; Milton and Arthington, 1983; Arthington and Lloyd, 1989; Kailola *et al.*, 1999). *Xiphophorus helleri*, which originates from eastern drainages of central America (Mexico southward to northern Honduras) (Miller, 1966), is a livebearing species that exhibits sexual dimorphism, i.e. the males develop a long ‘sword’ from the lower rays of their caudal fin and their anal fin becomes modified to form a gonopodium (intromittent organ for internal fertilisation) (Constantz, 1984). Captive bred fish exhibit a variety of colours but are generally an overall bright orange, fish from wild populations on the other hand, are olive brown to green with a narrow lateral stripe, the male retaining the orange coloration in the sword of the caudal fin (Figure 1). While it is has been demonstrated that *G. holbrooki* is impacting on, and causing a decline in, the native freshwater fish fauna of both south-western and eastern Australia through both competition for limited food resources and habitat and aggressive behaviour (e.g. McKay, 1978; Arthington *et al.*, 1983; Hambleton *et al.*, 1996; Gill *et al.*, 1999), the effects of other poeciliids on the native fish fauna has attracted only limited research. It is known, however, that male *X. helleri* form long term hierarchies and are to an extent territorial, spending much of their time aggressively fighting with other males and possibly other species (Franck and Ribowski, 1993).

This paper reports the first finding of a self-maintaining population of *X. helleri* in southwestern Australia and aims to increase the public awareness of the impacts associated with the release of non-native species into Western Australia. It also...
Figure 1 Male green swordtail *Xiphophorus helleri*, 55 mm TL.

highlights the need for more stringent regulations regarding the importation of exotic species for the aquarium industry.

**MATERIALS AND METHODS**

As part of a fish survey of the inland waters between Perth and Murchison, a total of eight sites along a 60 km stretch of the Irwin River and its tributaries (near Dongara ca 360 km north of Perth) were sampled for fish during summer 1998/99 (Figure 2). Fish were captured using seine nets comprised of 3 mm woven mesh. Fish were identified, with those species native to southwestern Australia immediately returned to the water, while all individuals of the introduced green swordtail *Xiphophorus helleri* were anaesthetised in benzocaine and placed into 100% ethanol. The total length (TL), which excludes the sword, of each fish was measured to the nearest mm.

**RESULTS AND DISCUSSION**

*Xiphophorus helleri* was found to occur at five of the six sites (i.e. sites 2–5 and 7) sampled along a 42 km stretch of the Irwin River between the town bridge (site 2) and Strawberry Bridge (site 7) (salinity range 0.3 - 2.4 ppt) (Figure 2). No *X. helleri* was captured at the site sampled downstream of town bridge (i.e. site 1) which was at the mouth of the river (salinity = 13.7 ppt) or at the only site that contained water upstream of Strawberry Bridge (i.e. Depot Hill Rd – site 8) which was almost dry. No fish was captured at the site sampled on Sand Plain Creek (i.e. site 6), which had previously dried. The mean densities of *X. helleri* at sites 2–5 and 7 ranged from 0.05 to 5 fish m⁻², while the lengths of fish at these sites ranged from 13 to 56 mm TL, respectively. The presence of large numbers of very small juveniles, and the fact that many of the males had recently spawned and that some of the females were pregnant, demonstrates that the Irwin River population is self maintaining. Co-occurring species, at the sites downstream of the weir at Mountain Bridge (site 4), included black bream (*Acanthopagrus butcheri*), Swan River gobies (*Pseudogobius olor*), and sea mullet (*Mugil cephalus*). Although there are no data or museum records available on the distribution of fish in the Irwin River, it is possible that the endemic freshwater teleosts, the western pygmy perch *Edelina vittata* and the western minnow *Galaxias occidentalis*, were once (and still may be) in the catchment. Both of these species have been found by the first author in the Arrowsmith River which is only 10 km to the south of Sand Plain Creek, a tributary of the Irwin River.

Information regarding the impacts of *X. helleri* on the native fauna is unavailable, however, Arthington (1989) found this species in waters around Brisbane to be omnivorous, consuming algae, plant matter, aquatic invertebrates (e.g. chironomids, oligochaetes, coleopterans, trichopterans, hemipterans, molluscs and other fish) and also terrestrial invertebrates (e.g. insects and arachnids). They found that the majority of guts examined contained, on average, large amounts (at 88% by volume) of amorphic, partly digested material which included plant fragments, filamentous algae and diatoms. Since the reproductive cycle of female *X. helleri* apparently ceases only when water temperatures fall below
$15^\circC$ (Milton and Arthington 1983), this species is capable of reproducing for an extensive period throughout most of Western Australia, with only winter/spring in the south-west recording temperatures less than $15^\circC$. In the Brisbane region (a latitude similar to that of the Irwin River), over 30% of females were pregnant in every month of the year except June (Milton and Arthington, 1983), with new recruits also appearing in these months. Furthermore, individuals of this species can mature at a small size (ca 23 and 27 mm for females and males, respectively), have a higher mean fecundity than the extremely successful $G. \text{holbrooki}$ (ca 60 versus ca 23), have a short gestation period (between 24 and 63 days) and thus have the potential to produce up to 12 broods per year (Milton and Arthington, 1983; Kailola et al., 1999). This species can also tolerate a wide range of temperatures and salinities and is able to survive in oxygen deficient waters by gulping at the air-water interface (Arthington et al., 1986). Green swordtails, which may reach over 100 mm TL, have even been shown to out compete and dominate the aggressive and very successful $G. \text{holbrooki}$ (Arthington et al., 1986). Thus, while $X. \text{helleri}$ is only currently found in the Irwin River in Western Australia, the fact that it can utilise an array of food/prey types, produces live young, can generate very large populations in a short period, lacks environmental constraints and is able to coexist with and even outcompete $G. \text{holbrooki}$ (Milton and Arthington, 1983) makes the swordtail a species that should be declared a pest.

While it may not be possible to eradicate this species from the Irwin River, it may be possible to limit future introductions through both public education and the removal of this species from aquarium shops. The fact that many aquarium species are relatively hardy, easy to maintain and reproduce readily makes them a potential threat to the unique fauna of Western Australia should they escape or be released into the wild. It should be the responsibility of the Fisheries Department of
Western Australia to identify and then prohibit species which, if released into the wild, are capable of readily establishing feral populations. Future surveys of the south-west, particularly within populated areas, will undoubtedly reveal other non-native species that have established populations as a result of deliberate releases.

ACKNOWLEDGEMENTS

Thanks are extended to the Natural Heritage Trust, Fisheries WA, Water and Rivers Commission of WA and Murdoch University for funding the survey of the waters between Perth and Murchison. Thank you very much to Charlotte Morgan for help with the field work.

REFERENCES


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Cover: Nephrurus levis occidentalis from 32 km southeast of Onslow, Western Australia.
Illustration by Jill Ruse.
Lower Devonian trilobites from Cobar, New South Wales

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Abstract - A Lower Devonian (Lochkovian-Pragian) trilobite fauna from the Biddabirra Formation near Cobar, New South Wales, Australia includes 11 previously undescribed species (Alberticoryphe sp., Cornuproetus sp., Gerastos sandfordi sp. nov., Cyphaspis mcnamarai sp. nov., Kainops cf. ekphymus, Paciphacops sp., Acanthopyge (Lobopyge) edgecombei sp. nov., Crotalocephalus sp. and Leonaspis sp., a styginid sp., and a harpetid sp.). Three species belonging to the genera Paciphacops, Kainops, Acanthopyge (Lobopyge), and Leonaspis are preserved with sufficient detail to provide enough information to be coded and analysed by two cladistic analyses. The resulting cladograms provide justification for the monophyly of Paciphacops and further support for Kainops. Leonaspis sp. is placed as the most plesiomorphic species within the monophyletic Leonaspis.

INTRODUCTION

The Lochkovian-Pragian Biddabirra Formation (Glen 1987) has yielded a trilobite fauna containing twelve species, of which eleven have previously been undescribed. The species include the fragmentary material of a styginid and harpetid, internal and external moulds of Alberticoryphe sp., Cornuproetus sp., Gerastos sandfordi sp. nov., Cyphaspis mcnamarai sp. nov., Kainops cf. ekphymus, Paciphacops sp., Acanthopyge (Lobopyge) edgecombei sp. nov., Crotalocephalus sp., Leonaspis sp and Cordania buicki Ebach and Edgecombe, 1999. The taxonomic composition of the fauna is similar to other preserved clastic faunas (Jones et al. (1986), Wright and Chatterton (1988), Wright and Haas (1990)) and silicified faunas (Chatterton (1971), Chatterton et al. (1979) and Chatterton and Wright (1986)) in New South Wales, with the exception of Cordania buicki, the first record of Cordania Clarke, 1892 in Australia.

The Cobar fauna was previously recorded by Sherwin (1978b unpubl.), Sherwin (1980a unpubl.) and Sherwin in Glen (1987), as containing seven species. Cladistic analyses are undertaken for three species (Kainops cf. ekphymus, Paciphacops sp. and Leonaspis sp.). The first analysis of Paciphacops-Kainops, employs characters used by Ramsköld and Werdelin (1991). Input data include species not used in the original analysis (Paciphacops argentinus, P. crawfordae, P. waisfeldae and P. sp.). The Leonaspis analysis, using Ramsköld and Chatterton’s (1991) characters, includes Leonaspis sp. from Cobar. The analysis will attempt to use species with more than 45% of their characters coded.

All photographed and type specimens are held in the Australian Museum (prefix number AMF).

AGE

The Biddabirra Formation has a thickness of about 1.5 km, and lies stratigraphically between the lower Amphitheatre Group and the upper Amphitheatre Group within the Cobar Supergroup. The Biddabirra Formation is a sandy sequence above the C.S.A Siltstone and the lower Amphitheatre Group and below the upper Amphitheatre Group (Glen 1987). It consists of poorly outcropping, medium to thick bedded sandstones. Due to the lack of marker beds, the trilobite fauna cannot be accurately placed within the Biddabirra Formation. The presence of the brachiopod Howellella jaqueti Dun (1898) in the Biddabirra Formation was regarded as evidence for a Pragian age, possibly extending down into the Lochkovian (Sherwin, in Glen 1987). A more recent assessment of brachiopods in the Cobar Supergroup (Sherwin 1995) recognises the occurrence of H. jaqueti as probably Lochkovian. Trilobites in the Cobar fauna are consistent with a Lochkovian age.
as close comparisons can be made with species recognised as Lochkovian in other parts of New South Wales (e.g. *Kainops ekphymus* and *Crotalocephalus* sp. from the lower part of the Tangerang Formation in the Windellama district; Jones et al. (1986). *Cordania buicki* Ebach and Edgecombe 1999 constrains the age to the Lochkovian-Pragian interval, the most species closely related to the Cobar *C. buicki* being Lochkovian. *Alberlicoryphe* sp. is the only indicator of a post-Lochkovian age, with its closest comparison being *A. marshalli* from the Jesse Limestone (Emsian) at Limekilns, New South Wales (Wright and Chatterton 1988).

**SYSTEMATIC PALAEONTOLOGY AND CLADISTIC ANALYSES**

Order Corynexochida Kobayashi, 1935  
Suborder Illenina Janusson, 1959  
Superfamily I llenacea Hawle and Corda, 1847  
Family Styginidae Vogdes, 1890

*styginid gen. and sp. indet.*  
Figure 1 A, F & H

**Material examined**  
Cranidium AMF 106635, free cheek AMF 106637 and pygidium AMF 106636.

**Remarks**

Few Devonian species of styginids have been described in Australia. These include *Scutellum* (Scutellum) sp. (Strusz 1964), *S. calvum* Chatterton, 1971, *S. droseron* Holloway and Neil, 1982, *S. hollandi* Wright and Chatterton, 1988, *S. sudorum*, *Xyoeax eponcus* and styginidae gen. and sp. indet. (Holloway 1996), *Dentalscutellum hudsoni* Chatterton, 1971 and two unnamed styginid species (Wright and Chatterton 1988). A styginid from the Biddabirra Formation cannot be confidently assigned to a genus due to the lack of a complete cranidium and pygidium. However, the Cobar specimens do not compare especially closely with any of the described species. The sparsely granulated surface in the Cobar styginid contrasts with *Dentalscutellum hudsoni* Chatterton, 1971, *Scutellum droseron* and *S. calvum*, which all have tuberculated surfaces. *Scutellum hollandi* is distinguished from the Cobar stygind by a pair of tubercles located submedially in front of S1. The pygidium in *Scutellum hollandi* and *S. sudorum* is heavily ornamented, versus finely granulated in the Cobar stygind, and the doublure of the free cheek is densely terraced in the Cobar stygind versus more sparsely terraced in *Scutellum hollandi*. The Silurian *Australoscutellum* from New South Wales shares the smooth ornament of the Cobar stygind, but differs in possessing a median rib with partial subdivision into three ribs.

Order Ptychopariida Swinnerton, 1915  
Suborder Harpina Whittington, 1959  
Family Harpetidae Hawle and Corda, 1847

*Genus harpetid gen. and sp. indet.*  
Figure 1E & G

**Material examined**  
Cephalon AMF 106638

**Remarks**

The present material is too fragmentary to confidently assign it at the generic and species level. The Cobar species differs from other described Devonian harpetids found in New South Wales (Etheridge and Mitchell 1917; Fletcher 1975; Chatterton and Campbell 1980) by its developed caeca on the genal roll that anastomose to the wide external rim. A combination of both these characters are present in several species of *Scotoharpes* Lamont, 1948 and *Hibbertia* Jones and Woodward, 1898 and cannot be considered to be a defining feature of either genus. The well developed caeca on the genal roll and wide rim are absent from *Scotoharpes trinucleoides* (Etheridge and Mitchell 1917) from Yass, New South Wales, *Lioharpes nymageensis* Fletcher, (1975) from near Cobar, New South Wales and, present in the Silurian *Scotoharpes molongloensis* Chatterton and Campbell, 1980 from the Yass Basin, New South Wales.

Order Proetida Fortey and Owens, 1975  
Superfamily Proetoidea Hawle and Corda, 1847

Family Proetidae Salter, 1864  
Subfamily Tropidocoryphinae Pribyl, 1946  
(= Prionopeltiinae Pribyl, 1946; Proetidellinae Hupé, 1953; Decoroproetinae Erben, 1966)

*Genus Alberlicoryphe* Erben, 1966

**Type Species**  
*Astycoryphe cogneyi* Alberti, 1964; Lower Devonian (Pragian), Morocco.

*Alberlicoryphe* sp.  
Figure 1 B, C, D & I

**Material Examined**  
Cranidium AMF 106639, free cheeks AMF 106640, AMF 106646 and pygidium AMF 106641.
Figure 1  Styginid gen. and sp. indet, A. Dorsal view of cranidium (internal mould), X 4.2, AMF 106635; F. Dorsal view pygidium (internal mould), X 4.5, AMF 106636; H. Dorsal view of free cheek (internal mould), X 4.5, AMF 106637; E & G Harpetic gen. and sp. indet, E. Dorsal view of cephalon (internal mould), X 4, AMF 106638; G. Dorsolateral view of cephalon (internal mould), X 4, AMF 106638; B, C, D & I Alberticoryphie sp., B. Dorsal view of cranidium (internal mould), X 4.5, AMF 106639; C. Dorsal view of free cheek (internal mould), X4.5, AMF 106640; D. Dorsal view of pygidium (external mould), X 4.5, AMF 106641; I. Dorsal view of free cheek (internal mould), X4.5, AMF 106646.
Description

Glabella weakly inflated, elongate, longer (sag.) than wide (tr.), tapering forward to rounded frontal lobe; glabellar furrows weakly defined; preglabellar furrow deep and short medially, lengthening abaxially; prominent tropidium located close to the preglabellar furrow; border furrow wide (sag.) and gently concave in front of ridge. Anterior border roll convex, widest (sag.) medially. Glabellar ornament of fine granules; preglabellar furrow and anterior border furrow perforated by fine pits; anterior border roll with fine terrace lines. Wide (exsag.) border furrow continues onto free cheek, half way (tr.) across gena. Lateral border gently convex and wide (tr.), joined to convex short (exsag.) posterior border; genal spine long and strongly terraced. Free cheek sculpture smooth, with pits on posterior margin and genal spine; lateral border with terrace lines, continuing onto genal spine. Facial sutures not preserved.

Remarks

The cranidium of this species is typical of **Alberticoryphe** in its forward tapering glabella, relatively short preglabellar field for a tropidocoryphine, wide anterior border furrow and short anterior border. The pygidium displays anteromedially directed pleural furrows posteriorly and strong terracing.

Of Australian species, **Alberticoryphe** sp. most closely resembles **A. marshalli** Wright and Chatterton, 1988 from the Jesse Limestone, Limekilns, New South Wales. It differs in possessing a wider (sag.), non-terraced anterior border. The North African species **A. cogneyi** (Alberti, 1964) and **A. stirps** Alberti, 1966 differ in having a pronounced pygidial border, a shorter (sag.) area behind the terminal piece, and no postaxial ridge. **Alberticoryphe** sp., like **A. marshalli** (see Wright and Chatterton 1988) shows greater similarities to the Bohemian **A. chemazur** Snajdr, 1980 in having pronounced pygidal ridge and shallow interpleural furrows. The pleural ridges are considerably deeper in **Alberticoryphe tauron** Snajdr, 1980. Both Bohemian species differ from the Australian **Alberticoryphe** by having a wider (tr.) pygidal axis.

Subfamily Cornuproetinae Richter and Richter, 1919

**Genus Cornuproetus** Richter and Richter, 1919

Type Species

**Gerastos cornutus** Goldfuss, 1843; Middle Devonian; Germany.

**Cornuproetus** sp. Figure 2

Material Examined

Cranidia AMF 106647, AMF 106649, AMF 107920, and pygidia AMF 106652, AMF 106653.

Description

Glabella elongate, subquadrate, gently tapering forwards, inflated, with a distinct constriction in front of mid length. Preglabellar furrow narrow, shortest (sag.); anterior border furrow short (sag.), anterior border twice the length of anterior border furrow medially, convex forwards in lateral view with a prominent roll. Occipital ring long (sag.), 1/4 length (sag.) of glabella and equal in length medially and distally; large, triangular lateral occipital lobes defined by faint furrows, 50 narrow (sag.) and deep. Axial furrows narrow and deep; palpebral lobe steeply inclined and convex outwards between γ and δ. Sculpture of fine granules and terracing on anterior border and pitting on the lateral margins of the preglabellar field (exsag.).

Hyopostome, free cheek and thorax unknown.

Pygidium semi-circular except for slightly transverse posteromedial margin, with sagittal length (including articulating half ring) 80 percent of width (tr.), axial width (tr.) 46–50 percent pygidal width (tr.); axial furrows wide, shallowing posteriorly, first ring furrow longest (sag.); seven axial rings plus a short, vaulted terminal piece. Four pleural furrows present, with distinct, narrow interpleural furrows; pleural furrows wide, shallowing medially, efacings abaxially. Pleural and interpleural furrows shallow behind border furrow; border wide, slightly lengthening posteromedially; border furrow shallow, prominent along whole pygidal margin, continuous with axial furrows, shallowing slightly behind terminal piece. Whole pygidium evenly granulated.

Remarks

**Cornuproetus** sp. displays many similarities to the broken specimens from Mudgee, N.S.W., assigned to **Cornuproetus** by Chatterton and Wright (1986). Both share a strongly terraced anterior border, which is longer (sag.) in the Mudgee species. The Victorian species described by Talent (1963, p.108, Figure 76 D) has a longer (sag.) anterior border.
Figure 2  *Comuproetus* sp., A, B. Dorsal and left lateral views of cranidium (internal mould), X 4.5, AMF 106647; C. Dorsal view of pygidium (internal mould), X 4.5, AMF 106652; D. Dorsal view of cranidium (internal mould), X 4.2, AMF 106649; E. Dorsal view of cranidium (external mould), X 4.2, AMF 107920; F. Right lateral view of pygidium (external mould), X 4.5, AMF 106652; I. Posterior view of pygidium (external mould), X 4.5, AMF 106653; J. Dorsal view of pygidium (external mould), X 4.5, AMF 106653; G. Dorsal view of free cheek (external mould), X 4, AMF 106650; H. Dorsal view of free cheek (external mould), X 4, AMF 106651.
than the Mudgee species. Talent’s (1963, Figure 77 C 15) is regarded herein as *Coniproetus* Alberti, 1966, based on its wide anterior border (sag.), strongly tapering glabella and narrow occipital ring. *Interproetus albertii* Chatterton and Campbell, 1980 (see Siveter 1989 for discussion of *Interproetus*) from the Wenlockian near Canberra, ACT, has a heavily tuberculated glabella and wide preglabellar field, both absent in the Cobar *Cornuproetus*.

**Genus Gerastos** Goldfuss, 1843

Type Species

*Proetus cuvieri* Steininger, 1831; Middle Devonian, Germany.

*Gerastos sandfordi* sp. nov.

Figures 3 and 4

**Material Examined**

*Holotype*

*Crandium* AMF 106655

*Paratypes*

*Cranidia* AMF 106648, AMF 106654 free cheek AMF 106656 and pygidia AMF 106658 and AMF 106657.

**Diagnosis**

Glabella strongly inflated, triangular (in lateral view), over-hanging wide anterior border with prominent roll. Anterior border furrow wide, continuous with lateral glabellar furrows; anterior area of fixigena inflated. Librigena tapering posteriorly to form small, thorn-like genal spine. Pygidium with seven axial rings; pygidial border wide, doublure strongly terraced; shallow border furrow around whole pygidial margin.

**Description**

Glabella strongly inflated, tapering forward with rounded, tapered frontal lobe; in lateral view, cranidium equal in width (sag.) and height; preglabellar field absent, anterior border wide (sag.) with prominent roll; anterior border furrow short (sag.) medially, widening distally. Glabella posteriorly inflated, markedly higher in front of SO and occipital ring; in dorsal view LO short (sag.), 25 percent of glabella and occipital length (sag.), lengthening distally, with subdued anterior notch exsagittally; SI weakly impressed distally, effacing postero-medially. SO deep and wide, approximately equal across width (sag.); facial suture convergent in front of palpebral lobes, lateral border wide (tr.), thinning posteriorly, with a prominent roll; anterior border furrow narrow. Posterior border furrow deep; γ to ε subovate, ε to ξ outwardly concave, adaxially directed to ω. Sculpture on cranidium granulated; terracing on lateral border and pitting on eye furrow.

Librigenal width (tr.) half of maximum length (exsag.); field inflated with small granules distributed evenly on internal and external moulds, rising steeply anteriorly to subocular furrow. Subocular furrow wide (tr.) and continuous around eye; posterior border short (exsag.), visual surface unknown. Lateral border wide and deeply incised with posterior outward convexity, shallowly posteriorly near genal angle. Lateral border wide (tr.) and inflated, tapering posteriorly to form small, thorn-like genal spine. Posterior border furrow deeply incised, narrow.

Hypostome and thorax unknown.

Pygidium with sagittal length (including articulating half ring) 90 percent of width; axial width (tr.) 45 percent of pygidial width (tr.); axial furrow wide, deflected laterally around first axial ring, then gently posteriorly convergent. Second axial ring with gentle “W” shape along posterior and anterior edges; seven axial rings and terminal piece, ring furrows shallowing and narrowing posteriorly, last furrow distinct; axis strongly raised above pleural field. Five pleural ribs, pleural furrows shallow and wide, shallowly posteriorly; interpleural furrows narrow, first two variably distinct on internal mould. Border wide, and doublure strongly terraced; shallow border furrow prominent around whole pygidial margin, confluent with axial furrows directly behind terminal piece. Sculpture consisting of granules concentrated medially on axial rings.

**Remarks**

The Cobar species possesses a distinctive inflated glabella that tapers forward, lack of a preglabellar field, a prominently rolled (sag.) anterior border, and reduced genal spine that are characteristic of *Gerastos* (Adrain 1997). The discovery of *Gerastos* from the Cobar region of New South Wales extends the generic range from the Canadian Arctic, Europe, Turkey and North Africa to Australia. Lütke (1990) assigned *Devonoproetus* Lütke, 1990 as a subgenus of *Gerastos*. However, Adrain (1997) doubted that it had any potential apomorphic affinities to *Gerastos* and placed *Devonoproetus* as a subjective synonym of *Proetus* s.s. (see Adrain 1997 pp. 25–27). Feist and Talent (2000) reject Adrain’s (1997) synonymy believing a ‘direct ancestor-descendant relationship between both taxa’ justifies *Devonoproetus* as a subgenus of *Proetus* (Feist and Talent 2000). Establishing a subgenus based on a tenuous ancestor-descendant relationship between two species is unwarranted. The synonymy of Adrain (1997) is supported herein.
Gerastos sandfordi is unusual in having a prominent pygidial border furrow, which is also seen in all Bohemian species with the exception of the G. retroflexus (Barrande 1852) group, but is absent in all Arctic Canadian Silurian species described by Adrain (1997). Gerastos sandfordi has many similarities with the Bohemian species G. kazan Šnajdr, 1980, including a granulose glabella and wide anterior border. The prominent, deep anterior border furrow present in G. sandfordi is absent from G. kazan. Gerastos sandfordi differs from all Bohemian Gerastos (with the exception of G. gagis Šnajdr 1980), G. expectatus (Přibyl 1964) and G. confusus (Hawle and Corda 1847) group by its triangular glabellar (in lateral view) and prominent wide (sag.) anterior border. The predominant overhanging glabella and the anterior inflation of the fixigena in G. sandfordi are absent in each of the Bohemian species.

Etymology
After Andrew C. Sandford.
Figure 4 Cerastos sandfordi sp. nov., A, B, D. Dorsal, anterior and left lateral views of cranidium (internal), X4 AMF 106655; C, E, F. Dorsal, posterior and left lateral views of pygidium (internal), X4.5, AMF 106658.

Family Aulacopleuridae Angelin, 1854
Subfamily Otarioninae Richter and Richter, 1926
Tribe Otarionini Richter and Richter, 1926
Genus Cyphaspis Burmeister, 1843

Type Species Phacops ceratophthalmus Goldfuss, 1843; Eifelian, Germany.

Remarks Cyphaspis was defined by Adrain and Chatterton (1994) as possessing a short, inflated glabella, a short preglabellar field, strong tuberculation, eleven thoracic segments and three pygidial axial rings (Adrain and Chatterton 1994). These characters justify the assignment of a Cobar species to the genus.

Cyphaspis mcnamarai sp. nov.

Material Examined

Holotype Cranidium AMF 106659.
Figure 5  *Cyphaspis mcnamari* sp. nov., A. Dorsal view of cranidium (internal), X 4, AMF 106659; B. Anterior view of cranidium (internal), X 4, AMF 106659; C. Dorsal view of cranidium (internal), X 4, AMF 106660; D. Left lateral view of cranidium (internal), X 4, AMF 106659; E. Right lateral view of cranidium (internal), X 4, AMF 106660; F. Anterior view of cranidium (internal), X 4, AMF 106660; G. Left lateral view of cephalon and part of thorax, X 5, AMF 106661; H. Dorsal view of cephalon and part of thorax, X 5, AMF 106661, I. Dorsal view of complete exoskeleton, X 4.5, AMF 106662; J. Right lateral view of complete exoskeleton, X 4.5, AMF 106662.

Paratypes
Cranidium AMF 106660, cephalon with thorax attached AMF 106661 and complete exoskeleton AMF 106662.

Diagnosis
Glabella inflated anteriorly, over-hanging wide anterior border and deep anterior border furrow; S1 wide and deep, continuous with S0; L1 inflated. Pygidium small, with four axial rings.

Description
Cranidial length subequal to width across palpebral lobes; anterior border of equal length
sagittally and exsagittally, with prominent dorsal convexity; anterior border furrow deep and narrow, short (sag.). Anterior sections of facial suture running approximately straight forward in front of palpebral lobes. In lateral view suture forming an asymmetrical inverted “U” shape; preglabellar field with gentle dorsal convexity. Preglabellar furrow prominent, semi circular in outline, short sagittally and subequal in width. Glabella inflated anteriorly, anterior part overhanging anterior border (when anterior border is held horizontal); in lateral view, glabella more than 50 percent of cephalic height, 1/3 of cephalic width (tr.); in lateral view, preglabellar field approximately twice the length of anterior border. LI reniform, prominent, convex outward. Glabellar ornament of even, densely scattered, small to moderate sized tubercles, less numerous on preglabellar field; anterior border bearing abundant coarse granules. Axial furrows shallow, wide, converging anteriorly into preglabellar furrow. SI deep and wide, forming a steep side on glabella. S2 shallow, effacing posteromedially, S3 indistinct. SO moderately deep and wide, with glabella rising steeply (sag.). Palpebral area strongly convex, high, eye unknown. Librigenae steep (exsag.), with a line of evenly spaced tubercles on lateral border; genal spine unknown.

Hypostome unknown.

Thorax of 11 segments, axial spine not preserved on sixth segment but margin broken in sole complete specimen. Axial rings and pleurae narrowing (tr.) posteriorly, with fulcrum set midway between axial furrow and lateral margin. Axial furrow shallow; pleural furrows shallow and wide, tapering laterally. In lateral view last four axial rings with preannulus. Pleurae wide (tr.); pleural tip with small articulating facet, longest (exsag.) on sixth pleural band, absent on first pleural band. Tubercles present on axial rings and pleurae, forming irregular rows.

Pygidium small, axial furrows moderately deep, remain constant around whole axis. Axis with four distinct rings; last ring merged with terminal piece. Ring furrows deep, narrow; the first with a pseudo-articulating half ring. Pleural furrows deep and confluent with axial furrow; pleural furrows becoming shallow posteriorly; interpleural furrows, narrow and distinct. Rows of irregular tubercles on most anterior axial rings and pleural ribs.

Remarks

The glabella in Cyphaspis memmarai differs from that of other NSW species of Cyphaspis as it overhangs the anterior cranial border (in lateral view) and expands anteriorly. Cyphaspis memmarai also has a wide anterior border (sag.) and an inflated L1, absent in both Cyphaspis dabroivi (Chatterton, 1971) from the Emsian Taemas Limestone, and Cyphaspis horani (Etheridge and Mitchell, 1893) from the Ludlow Yarwood Siltstone Member, near Yass.

There are no unique features that unite New South Wales Cyphaspis, however the considerable differences in age (Ludlow to Emsian) may indicate a large number of missing species, or suggest several separate migrations, possibly from Laurentia. Support for the later is seen in the closer resemblances between C. dabroivi and species from England and northwestern Canada (see Adrain and Chatterton 1996), than species from New South Wales.

Etymology

After Dr. Kenneth J. McNamara.

Order Phacopida Salter, 1864

Suborder Cheirurina Harrington and Leanza, 1957

Family Cheiruridae Salter, 1864

Subfamily Cheirurinae Salter, 1864

Genus Crotalocephalus Salter, 1853

Type Species

Cheiruris pengellyi Whidbourne, 1889; Middle Devonian (Givetian), England; see Lane (1971).

Crotalocephalus sp.

Material Examined

Cranidium AMF 106642 and hypostome AMF 106643.

Remarks

Crotalocephalus sp. from the Cobar fauna displays characters typical of the genus (sensu Chatterton and Wright 1986), such as the continuation of SI with S0, wide fixigenae and the presence of a genal spine, all absent from the somewhat similar Victorian genus Azyptyx Holloway, 1991. Crotalocephalus sp. is distinct from all described Victorian and New South Wales species.

Crotalocephalus sp. differs from Crotalocephalus oxina Holloway and Neil, 1982 from Lochkovian strata in the Mount Ida Formation of Victoria by its medially subdued S2, medially effaced S3 and squat hypostome with a concave inwards lateral border. Crotalocephalus silverdalensis Etheridge and Mitchell, 1917 is alleged to occur both in Victoria (Phillip 1962) and New South Wales (Fletcher 1975), although Holloway and Neil (1982) questioned the conspecificity of the material. It is distinguished from Crotalocephalus sp. by a distinctly shallow SI that is continuous with the occipital ring.
Figure 6  

*Crotalocephalus* sp., D. Dorsal view of hypostome (internal), X 3.5, AMF 106643; E. Dorsal view of cephalon (external), X 3, AMF 106642; *Leonaspis* sp., A. Anterior-dorsal view of cephalon (internal), X 10, AMF 106644; B. Dorsal view of pygidium (external), X10, AMF 106645; C. Dorsal view of thorax attached to pygidium (external), X 8.5, AMF 106685; F. Left lateral view of free cheek (external), X 8.5, AMF 106683; G. Left lateral view of free cheek (external), X 8.5, AMF 106684.

*Crotalocephalus packhami* Strusz, 1964, *Crotalocephalus sculptus* Etheridge and Mitchell, 1917 and *Crotalocephalus regius* Foldvary, 1970 have continuous S2 and S3 furrows, absent from the Cobar species. Similarities between the Cobar *Crotalocephalus* and *Crotalocephalus* sp. of Jones et al. 1986, from the Lochkovian Tangerang Formation, Windellama District, include a subdued S2 and long S0 medially. However the Tangerang species has a continuous S3 and more tuberculate glabella. The
Victorian *Crotalocephalus* sp. of Talent (1963) was described as “a juvenile [and therefore] no attempt [was] made to determine its specific affinities”. However, it differs from the Cobar species in having a continuous S3 furrow, a secondary sagittal furrow that dissects L3 medially, S1 not converging with S0 medially and a greatly expanded frontal glabellar lobe.

**Suborder Phacopina Struve, 1847**

**Family Phacopidae Hawle and Corda, 1847**

**Genus Kainops** Ramskold and Werdelin, 1991

**Type species**

*Paciphacops (Paciphacops) microps* Chatterton et al., 1979; Lower Devonian (late Lochkovian – early Pragian), New South Wales, Australia.

**Remarks**


**Kainops cf. ekphymus** (Jones et al., 1986)

**Figure 7 and Figure 8 A & B**

**Material Examined**

Cephala AMF 105636, AMF 105637, AMF 105639 and AMF 105643. Pygidia AMF 105638, 105640 and 105644, thorax articulated to pygidium AMF 105635. Unfigurcd material consists of 10 cephala and seven pygidia.

**Description**

Length (sag.) of cephalon about half of its width (tr.). Glabella inflated, inclined anteriorly, not overhanging anterior cephalic border. Axial furrows deep [Character 14:2 of Ramskold and Werdelin 1991], diverging at 60 degrees in front of LI. LI large, equal in length (sag.) to occipital ring, but wider (tr.), with a large, distinct adaxial ridge [Character 5:2 of Ramskold and Werdelin 1991]. Intercalating ring defined sagittally. S2 impressed across most of glabella; S3 well defined. Length between S1 and S2 equal to that between S2 and S3. Occipital ring wide, tapering strongly laterally (tr.) behind L1 lateral lobe. Eye greater in height than in length (exsag.), situated anteriorly, mid length (exsag.) of palpebral lobe opposite posterior edge of S3. 18 files of lenses, with a maximum of nine lenses per file; lens count (anterior to posterior) is 678 789 877 776 ??? ??, sclera are thin, slightly thickened dorsally. Palpebral area inflated, higher than visual surface [Character 13:2 of Ramskold and Werdelin 1991]; palpebral furrow deep and distinct [Character 15:2 of Ramskold and Werdelin 1991] continuous across palpebral area (exsag.); deepest and widest posteriorly. Genal field slopes steeply to lateral border furrow; palpebral area gently convex (exsag.). Posterior border furrow evenly deep and wide, weakly directed backwards across distal half, reflected at 90 degrees to lateral border furrow retaining the same width and depth; beneath eye lateral border furrow narrows anteriorly. Genal angle wide, rounded, without spine or node. Posterior border short (exsag.), abruptly widening distal to fulcrum, forming a “J” curve. Tubercles of similar, moderate size, evenly spread over glabella [Character 8:4 of Ramskold and Werdelin 1991], palpebral area and genal field, large granules on ventral margin and doublure, becoming smaller anteriorly. Granulation on cephalic border becomes finer toward the ventral edge of the lateral border; no granulation in furrows.

Hypostome unknown.

Thorax of 11 segments, tapering posteriorly between the fifth and 11th segment. Axis does not taper posteriorly; axial furrow narrow. Abaxial notches present on axial rings, rings arched (tr.) and inclined posteriorly. Pleurae narrow (tr.) distal to fulcrum. Posterior margin of pleurae behind the articulating facet with a posteriorly aligned, rounded tip. Pleural furrows narrow and deep (exsag.), pleural ribs and pleural furrows granulated on internal mould; little granulation on axial rings and furrows.

Pygidium semi-oval, with nine axial rings and terminal piece of up to 3–4 axial rings. In lateral view the axis inclines at 50 degrees, and the pleurae 40 degrees posteriorly. Axis tapers posteriorly to form a blunt terminal piece. Anterior ring highly arched, becoming less so posteriorly; first two or three rings furrows with prominent pseudo-articulating half ring, anterior four axial rings with shallow “W” shape. Five congruent pleural segments [30:2] with six distinct, deep, pleural furrows faintly widening abaxially; seventh pleural furrow narrow (tr.). Interpleural furrows thin, first four distinctly impressed across most of pleural field, fifth weak [Character 31:2 of Ramskold and Werdelin 1991]. Axial ring furrows shallowing medially, becoming moderately deep and continuous between first and ninth axial ring. Border distinct, defined by termination of the pleural furrows to form a high, steep area that narrows posteriorly. No postaxial ridge. Pygidium evenly covered with large granules, except in pleural and axial furrows. Four likely bands of large
granules present on each pleura, and two on each axial ring.

Remarks
Character coding for *Kainops cf. ekphymus* using the 32 characters of Ramsköld and Werdelin (1991), is as follows: 30312 12470 22222 311?? ??3?? 22002 23. *Kainops ekphymus* codes identically except for characters [1:0], [8:5], [9:0], [12:4], [13:0] and [19:3].
Assignment of the pygidium

The pygidium shares many characteristics with that of the small-eyed Australian *Paciphacops* and *Kainops* species, in particular, *K. microps* and *K. ekphymus*. Similarities include faint to absent posterior pleural and interpleural furrows and a wide (sag.) border behind the terminal piece. Both these characters are absent from the large eyed Australian *Paciphacops* species, thus justifying the association of the only phacopid pygidium in the Biddabirra Formation to *K. cf. ekphymus* rather than to the co-occurring *Paciphacops* sp.

Discussion

*Kainops microps* and *K. cf. ekphymus* are very similar apart from a wider (sag.) occipital ring and fainter S2 and S3 in *K. microps*, and a far more heavily tuberculate glabella in *K. cf. ekphymus*. The eye is set lower in elevation, and the palpebral areas are more inflated in *K. microps*. The pygidial axis in *K. cf. ekphymus* has a distinctive 'W' formation, not as pronounced in *K. microps*, and a widened anterior furrow is absent in *K. cf. ekphymus*. *Kainops cf. ekphymus* is distinguished from *K. ekphymus* by its narrow (tr.) and long (sag.) glabella and, its weak

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**Figure 8** *Kainops cf. ekphymus*, A & B. dorsolateral and dorsal view of pygidium, external mould, AMF 105644; C-F. *Paciphacops* sp.; C and F internal dorsal and left lateral of cephalon, AMF 105641; D lateral view of left eye, AMF 105641 and E external dorsal of cephalon, AMF 105642. All specimens X 2.5 magnification.
and short (tr.) S2 and S3 furrows. *K. ekphymus* was considered a junior synonym of *K. microps* by Ramsköld and Werdelin (1991), as they regarded all differences in morphology to be due to the preservation (*K. ekphymus* is preserved as distorted moulds and *K. microps* as undistorted silicified material). I consider that several coding differences (listed above) justify specific distinctness.

Genus *Paciphacops* Maksimova, 1972

Type species

*Phacops logani* Hall, 1861; Lower Devonian (Lochkovian), New York.

*Paciphacops* sp.

Figure 8 C-F

Material Examined

Cephalan AMF 105642 and 105641.

Description

Length (sag.) of cephalon about 70 percent of its width (tr.). Frontal lobe strongly inflated, wide, almost twice width (tr.) of occipital ring (tr.). Axial furrows diverging at 60 to 70 degrees, deep and wide [14:2], forming a vertical wall along glabella and an inclined wall against cheek. In lateral view the glabella overhangs anterior cephalic border. Occipital ring wide, highly arched, with anterior incision (exsag.) near abaxial edge, dissected by lateral groove (tr.) to form a lower step posteriorly, raised well above L1 medially; occipital node weak. L1 wide, with deep adaxial incisions. S0 deep, confluent with axial furrows. L1 distinct, wide (sag.) at mid line with distinct adaxial edge; S1 well impressed distally, becoming shallow medially, forming a small intercalating ring, distinctly inclined posteriorly [4:1]. S2 shallow and wide (tr.), S3 lightly impressed; maximum length between S1 and S2 nearly equal to length between S2 and S3; no rims present along S2 and S3. Eyes long (exsag.), reinforned, extending from anterior border furrow almost to posterior border furrow. S3 lenses in 14 files, with a maximum of five lenses in a file; lens count (anterior to posterior) 345 554 545 443 2; sclera wide [23:1]. Palpebral lobe raised well above palpebral area [13:0]. Palpebral furrow wide, shallowing medially [15:2], parallel to axial furrow posteriorly, curving adaxially anteriorly. Post-ocular area short [11:1], bordered by wide and shallow posterior furrow. Cheek concave outwardly beneath eye. Posterior border equal in height to distinctly arched palpebral area, flattens and widens laterally towards the rounded genae [16:3]. Posterior border furrow deep and wide (exsag.), widens abruptly, curving at 95 degrees into the lateral border furrow; anterior border furrow narrow.

Granulated tubercles strong and even on glabella [8:4]; intermittent with smaller tubercules. Palpebral area bearing numerous small, subdued tubercles. Smaller tubercles on occipital ring; posterior border evenly granulated; smaller granules on lateral border.

Hyposome, thorax and pygidium unknown.

Remarks

Character coding using Ramsköld and Werdelin’s (1991) characters for *Paciphacops* sp.: 30412 51410 13022 3722 2722. *Paciphacops* sp. shares similarities with the Australian *P. serratus* (Foerste, 1888), *P. crosslei* and *P. latigenalis* (Etheridge and Mitchell, 1895) in eye length (exsag.) and width (tr.), and the small post-ocular area. Compared with *P. crosslei* (Etheridge and Mitchell, 1895), it possesses fainter S2 and S3 furrows, a wider occipital ring [3:4], large L1 with distinct adaxial edge [5:2], a palpebral area lower than the palpebral lobe [13:0]. Compared with *P. sp.*, *P. latigenalis* has a shorter eye and hence a longer (exsag) post-ocular area [11:2]. *P. serratus* possesses deep S1 and S2, a wide (tr.) palpebral area behind a smaller eye compared to *P. sp.* *Paciphacops* sp. 1 (Ramsköld and Werdelin 1991), has an inflated palpebral area, higher than the eye, absent in *P. sp.* *P. crawfordae* Wright and Haas, 1990 differs in possessing a large post-ocular area, and small, anteriorly set eye. *Paciphacops* sp. does show features similar to North American taxa, such as a large eye, small post-ocular area, heavy tuberculation on the glabella, and a prominent (sag.) occipital ring with anterior incisions (exsag.). Compared to the North American, South American and European species, the Cobar *Paciphacops* has a wide glabella ornamented with large tubercules. The long (tr.) L1 with small adaxial nodes, deep S1, and occipital ring with a transverse groove of the Cobar species are not apparent in *P. logani* (Hall, 1861). The heavily tuberculated palpebral area, with wide and deep palpebral furrows of *P. sp* from Cobar is not present in *P. eldredgei* Ramsköld and Werdelin, 1991. L1 is shorter (tr.) in *P. birdsongensis* (Delo, 1940) and *P. campbelli* Ramsköld and Werdelin, 1991 with 2–3 lenses per row is shorter, compared to the 4 to 5 in *P. sp*. The palpebral area is inflated and markedly higher than the eye in *P. Hudsonicus* (Hall, 1861), but deflated and below the eye in *P. sp.* In the South American species *P. argentinus* (Thomas, 1905) and *P. waisfeldae* Edgecombe and Ramsköld, 1994, the palpebral area is inflated and higher than the eye and L1 is attached to an intercalating ring, without a long, deep S1 furrow as in *P. sp*.

Cladistic Analysis of *Kainops* and *Paciphacops*

Ramsköld and Werdelin (1991) erected *Kainops* on the basis that it formed a clade separate from
Paciphacops. However, Kainops was based on one homoplastic character state [25:1] (Ramskold and Werdelin 1991, Figure 3a & b) on one node, and Paciphacops on two character states [5:2] and [6:4] (their Figure 3a & b). The present analysis is restricted to Kainops and Paciphacops, hence more closely related outgroups than those used by Ramskold and Werdelin (1991), Podowrinella Clarkson, Eldredge and Henry, 1977 and Acernaspis Campbell 1967, should be used. In the broader analyses of Ramskold and Werdelin (1991), Ananaspsis and "Ananaspsis" proved to be the nearest outgroups to Paciphacops and Kainops, thus the most fully coded species of each of these groups, Ananaspsis decora Mánill, 1987 and "Ananaspsis" amelangorum Ramskold, 1985 have been selected as outgroups.

Data
The only alterations made to the original data set of Ramskold and Werdelin are the additions of Paciphacops crawfordae Wright and Haas, 1990 of the late Pragian from the Limekilns Formation, New South Wales, Australia, (character coding is as follows: 00012 3710 32222 21?1? 1?273 21220 02), P. waisfeldae Edgecombe and Ramskold, 1994 of the early Lochkovian from the Catavi formation, Bolivia and P. argentinus (Thomas, 1905) of the Pradilian or early Lochkovian Los Espejos Formation, San Juan, Argentina (see Edgecombe and Ramskold 1994, for character coding of both of these species), as well as Kainops cf. ekphymus and Paciphacops sp. from the Biddabirra Formation, New South Wales.

Computer analysis
Three analyses were run using the original 32 characters of Ramskold and Werdelin on PAUP version 3.11 (Swofford 1993). The heuristic search option and the TBR and ACCTRAN algorithms and characters were subject to successive reweighting (using the rescaled consistency index (RCI) scaled to a base weight of 1000) to find greater resolution amongst equally parsimonious cladograms. All species that have been designated as Paciphacops and Kainops have been used in this analysis. All trees are rooted keeping the ingroup monophyletic.

The sets of outgroups included in these analyses are Ananaspsis decora as outgroup, "Ananaspsis" amelangorum as outgroup and a combination of both A. decora and "A". amelangorum as outgroups.

Results
The unweighted using Ananaspsis decora produced 21 trees, 121 steps in length (CI 0.504, RI 0.520), compared to reweighting which found 63 trees (CI 0.636, RI 0.680) (Figure 9). Figure 10 shows characters optimised on the first tree. The unweighted run using "Ananaspsis" amelangorum as an outgroup retrieved an 12 trees of 120 steps (CI 0.525, RI 0.544), the reweighted run yielded a single most parsimonious tree (CI 0.639, RI 0.694) (Figure 11). The combined run (using both outgroups) yielded 411 trees, 127 steps in length (CI 0.496, RI 0.540) in the unweighted run and 3 trees (CI 0.581, RI 0.628) (Figure 12) in the reweighted run. Figure 13 shows characters optimised on the first tree.

Figure 9  Cladogram for phacopids using Ananaspsis decora as an outgroup. Strict consensus of 63 reweighted trees.
Remarks

In the *Anaspis decorata* run, *Kainops* is nested in *Paciphacops* in the reweighted consensus (Figure 9). Within *Paciphacops* an Australian clade consists of *P. serratus, P. crawfordae* and *P. latigenalis* forming a polytomy above *P. crosslei*. A North and South American *Paciphacops* clade, consisting of the North American species *P. hudsonicus, P. campbelli* Ramsköld and Werdelin 1991 and *P. birdsongensis* group as sister taxa to the South American species *P. argentinus* and *P. waisfeldae*. All *Kainops* species fall into a monophyletic clade supported by [19:1, 22:0, 23:1 and 24:2], as opposed to the single character state [25:1], on which the genus was erected in Ramsköld and Werdelin’s (1991) analysis.

In the “*Anaspis* amelangomum” run (Figure 11), most of *Kainops* again forms a distinct clade, consisting of *K. microps, K. invius, K. veles, K. ekphymus* and *K. cf. ekphymus* supported by four character states [1:3, 3:3, 24:2 and 26:1]. Within *Paciphacops*, *P. hudsonicus, P. campbelli* and *P. birdsongensis, P. argentinus* and *P. waisfeldae* form a sister group to *P. claviger, P. eldredgei, P. sp. 1* and *P. sp* and these together form a sister clade to the Australian *P. serratus, P. crosslei* and *P. latigenalis*. The sister grouping of *P. crawfordae* and *P. guttulus* is unusual (although supported by four character states), and is not seen in the *A. decorata* or combined runs (see below). The type species of *Paciphacops, P. logani* lies outside the large group of species normally assigned to that genus. In the combined run with both outgroups (Figure 12), *Kainops* is restricted to four taxa, *K. microps, K. veles, K. ekphymus*, and *K. cf. ekphymus*, and is supported by three characters [6:0, 11:2 and 28:0]. The Australian *Paciphacops* group consists of *P. crosslei*, *P. latigenalis* and *P. serratus* and *P. sp.* However the inclusion of *P. claviger* (Haas 1969) from Nevada, deeply nested with *P. crosslei* and *P. serratus* from New South Wales, is probably due to homoplasy rather than true homology. Another unusual grouping is that of *P. sp.l* from the Birdsong Shale of Termessee and *P. sp.* of the Biddabirra Formation of New South Wales. This clade is supported by five character states using ACCTRAN, but since only one is based on the cephalon [3:4], the significance of the others is doubtful (i.e., missing data are extended down tree by ACCTRAN). A predominantly American *Paciphacops* clade consists of two groupings; the two sister taxa *P. eldredgei* Ramsköld and Werdelin 1991, and *P. logani* and the North American *P. campbelli, P. hudsonicus, P. birdsongensis* together with the South American *P. waisfeldae* and *P. argentinus*. 

Figure 10 Cladogram for phacopids using *Anaspis decorata* as an outgroup. Character state changes on tree No 1 of 63 reweighted trees; Node 1 [6:3], [8:4], [17:1], [24:3], [26:2], [27:3], [28:2], [30:2]; Node 2 [1:3], [34:4], [5:2], [6:4], [16:3], [22:2]; Node 3 [12:3], [13:2], [29:3]; Node 4 [32:2], [27:2]; Node 5 [8:3], [12:2], [25:1], [29:1]; Node 6 [19:1], [22:0], [23:1], [24:2]; Node 7 [1:2], [6:3]; Node 8 [3:3]; Node 9 [6:5], [31:1], [32:3]; Node 10 [17:1], [19:3]; Node 11 [20:2], [26:3]; Node 12 [6:0], [11:2], [19:3], [28:0]; Node 13 [11:2]; Node 14 [3:3], [26:4]; Node 15 [zero length branch]; Node 16 [6:1], [7:2], [8:4], [9:0], [20:0], [23:0], [29:0]; Node 17 [31:3]; Node 18 [15:3], [24:4], [32:3]; Node 19 [1:2]; and Node 20 [130], [29:2], [36:1], [52:3].
Figure 11 Cladogram for phacopids using “Ananaspis” amelangorum as an outgroup. Character state changes on single reweighted tree; Node 1 [3:2], [6:3], [13:2], [16:3], [17:1], [20:1], [30:2], [31:2]; Node 2 [5:2], [6:4], [22:2]; Node 3 [8:4], [12:3]; Node 4 [6:5], [26:2], [29:1]; Node 5 [8:3], [20:0], [25:2], [31:0]; Node 6 [1:3], [19:2], [23:3]; Node 7 [1:3], [3:3], [24:2], [26:1]; Node 8 [12:2], [31:3], [32:3]; Node 9 [25:3], [29:3]; Node 10 [34:2], [20:2], [27:3]; Node 11 [6:4], [17:0], [19:3]; Node 12 [6:0], [11:2], [19:3], [28:0], [29:1]; Node 13 [6:3], [9:0]; Node 14 [3:3], [6:3], [9:0], [26:4]; Node 15 [20:0], [26:2]; Node 16 [8:3], [11:2]; Node 17 [12:2], [13:1]; Node 18 [15:3], [24:4], [32:3]; Node 19 [1:2] and Node 20 [6:1], [7:2], [8:4], [9:0], [23:0], [29:0].

Figure 12 Cladogram of Ananaspis decora and “Ananaspis” amelangorum as outgroups. Strict consensus of 3 reweighted trees.
**Figure 13** Cladogram of *Ananaspis decor*a and "Ananaspis" amelangorum as outgroups. Character state changes mapped on tree No 1 of 3 reweighted trees; Node 1 [20:1], [30:1], [31:2]; Node 2 [3:2], [6:3], [13:2], [16:3], [17:1], [25:1], [30:2]; Node 3 [5:2], [26:2]; Node 4 [1:3], [3:3], [6:4], [22:2]; Node 5 [8:4], [19:3]; Node 6 [3:2], [12:3], [23:3]; Node 7 [28:0], [11:2], [6:0]; Node 8 [6:5], [19:2], [20:2]; Node 9 [25:3]; Node 10 [8:3], [11:2], [31:0]; Node 11 [12:2], [31:3], [32:3]; Node 12 [13:0], [15:1], [26:3], [27:3]; Node 13 [17:0], [29:3]; Node 14 [9:2]; Node 15 [3:3], [26:4]; Node 16 [8:3]; Node 17 [6:1], [7:2], [9:0], [20:0], [23:0], [29:0]; Node 18 [5:1], [8:4], [11:0], [29:2]; Node 19 [3:4], [22:1], [26:5], [27:3], [29:0]; Node 20 [15:3], [24:4], [32:3]; and Node 21 [1:2].

**Taxonomic Implications**

Because it accommodates more taxa, the analysis using both outgroups is considered to be the methodologically superior interpretation of both Paciphacops and Kainops. The combined result of all three trees show:

1. Kainops and Paciphacops are monophyletic.
2. the possibility of a unique American Paciphacops clade consisting of North American *P. elderdigei*, *P. argentinus*, *P. campbelli* and *P. birdsongensis* and South American *P. waisfeldae* and *P. argentinus*. The American Paciphacops clade (with the exception of newly added South American taxa), has been noted by Ramskold and Werdelin (1991, Figure 2a & b);
3. a distinct Australian clade consisting of *P. serratus*, *P. crosslei*, *P. latigenalis*, which Ramskold and Werdelin (1991) resolved as a clade, but also including *P. crawfordae* and *P. sp.*, and;
4. the recognition of unconstrained species, *P. claviger*, *P. logani*, *P. crawfordae* and *K. guttulus*, that will only be resolved with the addition of complete specimens of known species, new taxa and new characters.

**Order Lichidae Moore, 1959**

**Superfamily Lichoidea sensu Fortey, 1997**

**Family Lichidae Hawle and Corda, 1847**

**Subfamily Trochurinae Phleger, 1936**

**Genus Acanthopyge Hawle and Corda, 1847**

**Subgenus Lobopyge Příbyl and Erben, 1952**

**Type Species**

*Lichas Branikensis* Barrande, 1872; Lower Devonian (Pragian), Czech Republic.

*Acanthopyge (Lobopyge) edgecombei* sp. nov.  

**Material Examined**

**Holotype**  
Cranidium AMF 106418

**Paratypes**  
Cranidia AMF 106417, AMF 106070, hypostome
AMF 106071 and pygida AMF 106069 and AMF 106472.

Diagnosis

Posterolateral cranidial lobe triangular, bullar lobes angular in shape, not rounded as in most Devonian species (*Acanthopyge* (Lobopyge) *campbelli* Chatterton and Wright, 1986, *A. (L.) australiformis* Chatterton et al., 1979 and *A. (L.) sinuata* (Ratte, 1886)). Sculpture on hypostomal middle body tuberculate and pitted. Marginal pygidial spine long, thin and outwardly directed.

Description

Cranidium trapezoidal, wider (tr.) than long (sag.). Bullar and posterolateral cranidial lobes inflated, and median glabellar lobe strongly inflated. Anterior margin convex medially, converging posteriorly to bound a highly arched and strongly inflated glabella medially. Sagittal region of median glabellar lobe the highest point on the cranidium. S1 converges to meet S0 medially, forming a short (sag.) and wide (tr.) occipital furrow; median tubercle between two prominent nodes on preoccipital glabellar region. Bullar lobes triangular, asymmetrically arched, sloping abaxially, distinctly larger than the trapezoidal posterolateral cranidial lobes. Posterolateral cranidial lobes convex. L0 shortens distally; S0 shallow medially, becoming deeper abaxially. Cranidium strongly tuberculate, with several large paired tubercles on glabella; tuberculation sparse on L0.
Hypostome squat, with long posterior border, posterior margin concave backward, with straight lateral margins. Border furrow widest and deepest opposite shoulder, shallowly medially, with uneven tubercles scattered on furrow margin. Posterior furrow on middle body effaces adaxially; wing short. Middle body with uneven tubercles concentrated anteriorly, coarsely pitted posteromedially.

Thorax unknown.

Pygidial axis inflated, longer (sag.) than wide (tr.), gently tapering, forming a blunt terminal piece with a prominent postaxial ridge. Distinct incision of first ring furrow abaxially, second ring furrow incomplete. Two distinct pairs of prominent pleurae with well defined interpleural and pleural furrows, form the two pairs of major pygidial spines. Major pygidial spines outwardly directed, evenly long (exsag.), tapering at extremities to form sharp tip. Posterior pleural region (behind second rib) lacks furrows, heavily ornamented with evenly scattered tubercles. Weak posterior border fused with posterior pleurae and postaxial ridge. Pair of posterior marginal spines, blunt and shorter than the major pygidial pleural spines, extend from raised margin. Distance between posterior marginal spines equal in width (tr.) to pygidial axis at second axial ring. Axial rings strongly tuberculate; evenly scattered tubercles on pleural ribs.

Remarks

A recent cladistic analysis of Acanthopyge (Lobopyge) found a consensus of 18 trees Ebach and Ahyong (2001; Figure 4) in which A. (L.) edgecombei and A. (L.) erinacea (Haas, 1968) are sister taxa in an unresolved clade consisting of the Australian species A. (L.) australis (McCoy, 1876), A. (L.) sinuata (Ratte, 1886), A. (L.) pustulosa Morzadec, 1983, A. (L.) campbelli Chatterton and Wright, 1986 and A. (L.) australiformis Chatterton et al., 1979.

Acanthopyge (Lobopyge) edgecombei is distinguished from A. (L.) erinacea (Haas, 1968) by longer posterior pygidial spines. The second posterior spines are posteriory directed in A. (L.) australis (McCoy, 1876), A. (L.) sp. 1 NSW Chatterton et al., 1979, A. (L.) campbelli Chatterton and Wright, 1986 versus outwardly directed in A. (L.) edgecombei. A subduced node present on the pygidial posterior border in A. (L.) sinuata (Ratte, 1886) is absent in A. (L.) edgecombei and a shorter pygidial ring furrow (tr.) in A. (L.) pustulosa Morzadec, 1983. The area between the posterior spine pair is larger in A. (L.) edgecombei than in A. (L.) australiformis Chatterton et al., 1979 and A. (L.) sinuata. S0 is sagittally wide in A. (L.) of Jones et al., 1986, but narrower with a median tubercle in A. (L.) edgecombei. A. (Lobopyge) sp. of Holloway and Neil, 1982, from the Mt Ida Formation in Victoria, has an inwardly directed posterior pygidial spine pair and wide (tr.) pygidial axis, both absent in A. (L.) edgecombei.

Cladistic Analysis

Computer treatment of data

The analyses were run using PAUP 3.11 with the same settings in the above *Paciphacops-Kainops* analysis. All characters were treated as unordered, and reweighted based on the rescaled consistency index using a base weight of 1000. Multistate taxa are treated as 'uncertain'. All analyses were run using the branch and bound search. All consistency (CI) and retention (RI) indices listed are from the shortest trees. All trees were rooted keeping the ingroup (*Leonaspis*) monophyletic.

Of the 14 coded *Leonaspis* species (13 in Ramskold and Chatterton 1991), only nine had less 45 percent of their characters missing and therefore were used in the analysis. Results from similar approaches (see Ebach and Ahyong 2001 and Kitching et al. 1998) concluded that an increase in the number of missing data led to more equally parsimonious trees and generated ambiguous results in some cladistic computer programs. In the *Leonaspis* analysis, 45 percent of the data represent up to two whole regions. Thus, deleted taxa are based on a combination of missing cranial, hypostomal, thoracic or pygidial features.

**Outgroup Selection**

*Keltneraspis jaanussoni* Chatterton and Perry, 1983 was suggested to be among the closest relatives of *Leonaspis* by Ramskold and Chatterton (1991). They considered that *Leonaspis* was not directly derived from *Keltneraspis* but rather that *Leonaspis* originated from a taxon similar to that giving rise to

![Figure 15](#) Reweighted consensus tree of the *Leonaspis* fourteen taxon run.

![Figure 16](#) Reweighted consensus tree of the *Leonaspis* nine taxon run.

![Figure 17](#) First tree of the reweighted consensus tree of *Leonaspis* nine taxon run; Node 1 [1:2], [2:1], [4:1], [31:1], [32:2], [33:1]; Node 2 [8:1], [10:1], [11:1], [17:2], [20:0], [21:1], [27:0], [29:2]; Node 3 [13:1], [14:2], [22:1], [24:2], [28:1], [32:2], [35:0]; Node 4 [1:0], [18:0], [25:1], [26:1]; Node 5 [5:1], [9:2], [26:1], [32:1]; Node 6 [10:0], [12:0], [16:1], [23:0]; Node 7 [9:1]; Node 8 [10:0], [17:1], [23:0]; Node 9 [7:0], [9:1], [24:0].
Kettneraspis. Hence, *Kettneraspis jaanussoni* is used as the outgroup for *Leonaspis* in this analysis.

**Data**

All characters used in this analysis are from Ramsköld and Chatterton's (1991) analysis. That work should be consulted for character definitions and codings.

The only alteration made to the original data set of Ramsköld and Chatterton is the addition of *Leonaspis* sp. from the Cobar fauna (character coding is as follows: 2000[0/1]0110001???121000?110?12011100/1)).

**Results**

**Fourteen Taxon Run**

The fourteen taxon run includes all 13 coded *Leonaspis* species from Ramsköld and Chatterton (1991) and *Leonaspis* sp. The reweighted analysis found 720 trees (CI 0.892, RI 0.827) (Figure 15).

**Remarks**

Using all coded taxa with equal weights yielded an unresolved consensus, regardless of its high consistency and retention indices (CI 0.762, RI 0.667). A reweighted run yielded two trichotomous clades, with *Leonaspis brittanica* Morzadec, 1969, *L. hastata* (Alberti, 1967) and *L. maura* (Alberti, 1969) forming one clade and *L. glabra* (Roemer, 1843), *L. hoernesii* (Barrande, 1846) and *L. truncata* (Hawle and Corda, 1847) forming another.

**Nine Taxon Run**

The unweighted run found 3 trees of 40 steps, (CI 0.800, RI 0.636). Reweighting yielded 2 trees (CI 0.929, RI 0.851) (Figure 16 and Figure 17).

**Remarks**

In the rewieghted run, *Leonaspis brittanica* from the Upper Emsian of France and the Upper Emsian Moroccan *L. maura* are grouped as sister taxa. A trichotomy is formed between the Turkish *Leonaspis belisarius* Haas, 1968, a clade containing the Bohemian *L. hoernesii*, *L. truncata* and Australian *L. johnkinsi* Etheridge and Mitchell, 1895 and the Bohemian sister taxa *L. lochovensis* Franti and Přibyl, 1949 and *L. leonhardi* Barrande, 1846. *Leonaspis* sp. is the most plesiomorphic taxon within *Leonaspis*.


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Neopomacentrus aquadulcis, a new species of Damselfish (Pomacentridae) from Eastern Papua New Guinea

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Abstract – Neopomacentrus aquadulcis, new species is described from 40 specimens, 15.1-45.7 mm SL, collected from the tidal reaches of freshwater streams in Milne Bay and Morobe provinces. It is clearly separable from other members of the genus on the basis of its very dark overall coloration and characteristic, broad-lobed caudal fin shape. It is also the only Neopomacentrus possessing a blackish caudal fin compared to the yellow (or yellow with dark margins) caudal fin seen in other members of the genus. It is only the fourth pomacentrid species known to occur in freshwater.

INTRODUCTION

Damselshies (Pomacentridae) are among the most speciose and conspicuous of all fishes inhabiting tropical and subtropical reefs. The family was reviewed by Allen (1991), who recognized 321 species in 28 genera. Since the publication of this work, 24 species have been added (see Allen and Adrim 2000 for a review), bringing the current total to 345 species, including a new taxon described herein. The present paper describes a species of Neopomacentrus, a genus that currently contains 14 species confined to the tropical Indo-west Pacific region. The new species was observed underwater and subsequently collected by the authors during three separate visits to eastern Papua New Guinea during 1999. It is notable in being one of only four members of this large family that is known to inhabit fresh and brackish waters.

Methods of counting and measuring are the same as those described by Allen (1972) except the length of the dorsal and anal spines are measured proximally from the base of the spine rather than from the point where the spine emerges from the scaly sheath. The gill raker at the middle of the first branchial arch is included in the lower-limb count. The last dorsal and anal soft rays is split at the base and is counted as a single element. The fraction “1/2” appearing in the scale count above the lateral line refers to a small truncated scale at the base of the dorsal fin.

Counts and proportions appearing in parentheses apply to the paratypes. Type specimens have been deposited at the Australian Museum, Sydney (AMS), and Western Australian Museum, Perth (WAM).

SYSTEMATICS

Neopomacentrus aquadulcis sp. nov.
Figure 1; Table 1

Material Examined

Holotype
WAM P.31636-001, 42.6 mm SL, mouth of freshwater stream at Lawadi Village, Milne Bay Province, Papua New Guinea (10°15.81'S, 150°43.14'E), 1.0 m, spear, G. Allen, 20 November 1999.

Paratypes
WAM P.31636-002, 9 specimens, 33.5–45.7 mm SL, collected with holotype. AMS 1.37954-001, 30 specimens, 15.1–45.5 mm SL, mouth of Saia River, Morobe Province, Papua New Guinea (07°21.92'S, 147°07.12'E), 1.5 m, spear, rotenone, A. Jenkins, 23 July, 22 November 1999.

Diagnosis
A species of the pomacentrid genus Neopomacentrus with the following combination of characters: dorsal rays XIII,10 or 11; anal rays II,10 or 11; pectoral rays 17 or 18; gill rakers on first branchial arch 5–7 + 14–16; tubed lateral-line scales 14–17; in life head and nape brown, grading posteriorly to dark charcoal grey over most of body; scales with paler centres, especially noticeable on head and anterior part or body; fins dark charcoal grey, nearly black; anterior margin of pelvic and anal fins narrowly bright blue.
Figure 1  *Neopomacentrus n. sp.*, holotype, 42.6 mm SL, Lawadi, Milne Bay Province, Papua New Guinea.

Description

Dorsal rays XIII,10 (9–10); anal rays II,10 (10–11); pectoral rays 18 (17–18); gill rakers on first branchial arch 5 + 15 (5–7 + 14–16), total rakers 20 (20–22); tubed lateral-line scales 14 (14–17); vertical scale rows from edge of opercle to caudal-fin base 28; scales above lateral line to base of middle dorsal spines 1 1/2; scales below lateral line to anus 8.

Body depth 2.2 (2.2–2.4) in standard length; maximum body width 2.3 (2.1–2.7) in depth; head length contained 3.2 (3.0–3.3) in standard length; snout 4.7 (4.4–5.5), eye 3.0 (3.0–3.3), interorbital space 3.4 (3.1–4.5), least depth of caudal peduncle 2.1 (2.1–2.4), length of caudal peduncle 1.9 (2.0–2.4), all in head length.

Mouth oblique, terminal, the maxilla reaching a vertical slightly beyond anterior edge of eye; teeth of jaws biserial, at least anteriorly; outer row teeth mainly incisiform with flattened or slightly notched tips, except a few conical teeth posteriorly, about 38–42 teeth in each jaw; secondary row of inconspicuous slender buttress teeth behind outer

Figure 2  *Neopomacentrus n. sp.*, about 55 mm TL, photographed underwater at Lawadi, Milne Bay Province, Papua New Guinea in 1.5 m depth.
Table 1 Proportional measurements of selected type specimens of *Neopomacentrus aquadulcis* as percentage of the standard length.

<table>
<thead>
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<th>Paratype 1</th>
<th>Paratype 2</th>
<th>Paratype 3</th>
<th>Paratype 4</th>
<th>Paratype 5</th>
<th>Paratype 6</th>
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</table>

row in spaces between them; single nasal opening on each side of snout; nostril with a low fleshy rim; about 23–25 sensory pores on each side of snout and on circumorbitals; preorbital and suborbital relatively narrow, the greatest depth about one-fourth eye diameter, ventral margin smooth; posterior margin of preopercle smooth; opercular series smooth except a blunt, flattened spine present on upper edge of opercle, near angle, and similar, but smaller spine on uppermost edge, just below lateral-line origin.

Scales of head and body finely ctenoid; preorbital, suborbital, snout, lips, chin, and isthmus naked; predorsal scales extending to level of front of eyes; preopercle with 3 scale rows (2 primary rows and row of smaller secondary scales near lower margin), rear margin narrowly naked; dorsal and anal fins with a basal scaly sheath; proximal half of caudal fin covered by scales; base of pectoral fins scaled; axillary scale of pelvic fins less than one-half length of pelvic spine.

Tubed lateral line scales ending below posterior spines or anterior soft rays of dorsal fin; pits or pores present on 3 (3–4) scales immediately posterior to last tubed scale; a series of 6 (6–9) pored or pitted scales mid-laterally on caudal peduncle extending to caudal base.

Origin of dorsal fin above third tubed scale of lateral line; spines of dorsal fin gradually increasing in length to posteriormost; membranes between spines moderately incised with posteriorly directed, pennant-like extensions at distal tip of each spine; first dorsal spine 2.9 (2.0–3.0) in sixth dorsal spine; sixth dorsal spine 0.9 (1.0–1.5) in last dorsal spine; last dorsal spine 2.1 (1.6–2.0) in head; longest soft dorsal rays prolonged into short filament in large adults, 1.1 (1.0–1.4) in head; length of dorsal-fin base 1.5 (1.5–1.7) in standard length; first anal spine 2.0 (2.0–2.5) in second anal spine; second anal spine 1.6 (1.5–1.8) in head; longest soft anal ray 1.1 (1.0–1.4) in head; base of anal fin 2.6 (1.5–1.8) in standard length; pelvic fin emarginate with broadly pointed lobes; caudal-fin length 0.9 (0.9–1.1) in head length; pectoral fin reaching a vertical through origin of anal fin, the longest ray 1.0 (1.0–1.1) in head length; filamentous tips of pelvic fins reaching to about base of first or second soft anal-fin ray; pelvic fin-length 1.0 (0.9–1.0) in head length.

Colour of holotype in alcohol: entirely blackish, including median and pelvic fins; tips of caudal lobes noticeably paler; pectoral fins with translucent membranes and dusky rays. The paratypes have a similar colouration.

Colour in life: head and nape brown, grading
posteriorly to dark charcoal grey over most of body; scales with paler centres, especially noticeable on head and anterior part or body; a faint blackish "ear" spot sometimes evident at origin of lateral line; fins dark charcoal grey, nearly black; anterior margin of pelvic and anal fins narrowly bright blue; outer portion of caudal lobes of nest-guarding or nuptial males broadly whitish; a black spot at base of uppermost pectoral rays.

Remarks

The genus Neopomacentrus Allen contains 14 species, including N. aquadulcis n. sp. The group is characterised by a relatively elongate shape (greatest depth 2.2-2.8 in SL), elongate soft dorsal and anal fin rays, frequently with prolonged caudal lobes, a smooth or weakly crenulate preopercular margin, and biserial teeth, those in the outer row having flattened or slightly notched tips. Most species occur on coral reefs, in contrast to the fresh and brackish water habitat that is characteristic of N. aquadulcis. Indeed, only three other pomacentrids, N. taeniurus and Pomacentrus taeniometopon of the Indo-west Pacific and Stegastes otophors of the western Atlantic, are known to occur in fresh and brackish waters (Allen, 1991). The new species is clearly separable from other members of the genus on the basis of its very dark overall coloration and characteristic, broad-lobed caudal-fin shape. Furthermore, it is the only Neopomacentrus possessing a blackish caudal fin; in most species the caudal is yellow or yellow with darkish margins. It occurs sympatrically with N. taeniurus, but significant colour differences provide easy differentiation: N. aquadulcis is overall blackish compared to the grey-brown colour of N. taeniurus, and the new species lacks yellow on the caudal, soft dorsal, and soft anal fins, all characteristic markings for N. taeniurus.

Neopomacentrus aquadulcis is presently known only from the north-eastern coast of mainland Papua New Guinea between the type locality (near East Cape, the easternmost extension of mainland Papua New Guinea) and Cape Roon on the Morobe coast. The typical habitat consists of the lower, tidal reaches of freshwater streams in either pure fresh or brackish water. At the type locality a population of approximately 50 fish were observed in the lowermost, 100 m-stretch of Lawadi Creek. During periods of extreme low tide the water was entirely fresh, but became gradually mixed with seawater with the rising tide. At the Saia River-collecting locality in Morobe province, water temperature was 24.5°C, pH 8.3 and current speed 0.5 m/s. Field observations in both collecting localities indicate a probable harem-type structure with a single nuptial male in company of up to about 10 smaller fish. Nesting was evident with nuptial males showing strong whitish borders on the caudal fin and occasionally “flashing” 2-3 whitish bars on the side of the body. Nesting appears most commonly among submerged fallen trees where fish can quickly retreat to shelter. Distinct nesting groups of N. taeniurus were seen in close proximity to the groups of N. aquadulcis at both collecting locations.

Etymology

The new species is named *aquadulcis* from the Latin meaning “sweet-water” with reference to the freshwater habitat in which it is found.

ACKNOWLEDGEMENTS

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REFERENCES


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The distribution of the Western Australian pill millipede, *Cynotelopus notabilis* Jeekel (Sphaerothriidae)

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Abstract — *Cynotelopus notabilis* Jeekel, the sole sphaerothriid species to be recorded from Western Australia, occurs in high-rainfall habitats along the southern coast of south-western Australia. Given the ecological requirements and low vagility of the species, it is likely to be prone to localized extinction events due to fire and habitat fragmentation.

INTRODUCTION

The south-west forest region of Western Australia has a rich Gondwanan invertebrate fauna (Hopper et al., 1996; Main and Main, 1991). However, some species have been described only recently and much of the terrestrial fauna, including both rare and widespread species, remains unnamed (Main, 1996). An interesting genus of pill millipede, *Cynotelopus*, was recently described by Jeekel (1986) from three specimens collected in 1927 from Normalup in the south-west. He stated that the specimens and genus were of particular interest because they belonged to the family Sphaerothriidae, a group which “was never before recorded from the western part of the continent.” The purpose of this note is to correct this misconception and to comment on the biology and distribution of the genus.

The specimens that form the basis of this study are lodged in the Western Australian Museum, Perth (WAM), while the type material, which has not been reexamined, is lodged in the South Australian Museum, Adelaide (SAM).

HISTORICAL RECORDS

In his account of the biogeography of the Western Australian fauna, Nicholls (1933) recorded the occurrence of pill millipedes (family Sphaerothriidae of the order Sphaerothriida) in the south-west from near Normalup. He noted that they were from “under logs, in karri country, along the bank of the Deep River...”. His opinion on their taxonomic affinity was that the species could not be referred to either of the two genera of sphaerothriids already known from eastern Australia and Tasmania. Main (1954) and Main and Edward (1968) included the “Oniscomorpha” (which comprises the Sphaerothriida and Glomerida) in a key for which the primary purpose was use by naturalists and university undergraduate students in field studies. At that time the pill millipedes, which were listed under the generic name *Cyliosomella*, were considered sufficiently abundant and widespread through the karri forest to be encountered by students and naturalists. Since that time to the present, undergraduate students at the Department of Zoology of the University of Western Australia have regularly examined specimens, mostly collected from the Pemberton area, as part of their arthropod systematics course.

Unfortunately, no representatives of the Deep River species were apparently retained in the collections of either the University of Western Australia (Nicholls' institution) or deposited in the Western Australian Museum, but there can be little doubt that it represents the species later described as *Cynotelopus notabilis* Jeekel, 1986. In view of the early records of the millipedes and the perception that they are abundant on the karri floor (mostly in and under rotting logs) it is unfortunate that the only specimens lodged in the Western Australian Museum are recently collected specimens, the earliest of which was collected in 1962. Thus the question now is whether the species has become rare in the western part of its assumed range, or whether it is a case of a widespread, abundant species having been neglected in the past by collectors. In order to assess the occurrence and distribution of the species, it is clear that it needs to be deliberately searched for and its distribution documented, along with observations on the viability of current habitats and populations. It is possible that some of Nicholls' *Cynotelopus* material was sent to overseas
museums or to K. Verhoeff, who described two millipede species based upon specimens forwarded by Nicholls (Verhoeff, 1936). Inquiries to the Museum für Naturkunde der Humboldt-Universität, Berlin, failed to locate any specimens of Western Australian pill millipedes.

IDENTITY

Pill millipedes are immediately distinguishable from other millipedes by their extremely stout body that is capable of rolling into a tight ball (Harvey and Yen, 1989). Males of *Cynotelopus notabilis* differ from those of other sphaerotheriids in the form of the pygidium, which is concave and bears a small hook-like structure (Figure 3; Jeekel, 1986). The gonopods of males from Torbay Hill and West Cape Howe National Park were compared with the illustrations of the holotype provided by Jeekel (1986). No differences could be detected, and we are confident that all populations sampled represent a single species.

Material Examined

Australia: Western Australia: 1 ♂, Denmark, Pininger’s Pimple, 34°58’S, 117°21’E, 17 July 1962, under rock on large granite tor, P. Cawthorn (WAM 98/2120); 2 ♂, 1 ♀, Torbay Hill, 35°05’S, 117°37’E, 1978, B.Y. Main (WAM 98/1247-1249); 1 ♂, 1 ♀, same data except 30-31 January 1978 (WAM 98/1250-1251); 1 ♀, same data except 2 December 1982 (WAM 98/1252); 1 ♀, same data except 3 March 1983 (WAM T40851); 1 ♀, 1 juvenile, same data except 5 March 1983 (WAM 98/1263-1264); 6 ♀, 4 juveniles, Torbay Hill, cottage site, ‘Beck’s Place’, 19 February 1983, B.Y. Main (WAM 98/1253-1262); 1 ♂, Torbay Hill, Lot 40, 35°05’S, 117°37’E, 14 October 1997, B.Y. Main (WAM 98/1265); 1 ♂, 3 ♀, Torbay Hill, W. of Torbay, 35°05’S, 117°37’E, 29 December 1981, leaf litter of karri forest, G.W. Kendrick (WAM 98/2121-2124); 1 juvenile, Walpole-Nornalup National Park, Tinglewood, 35°00’S, 116°38’E, 7 January 1999, under karri bark, S.L. Judd (WAM 99/2538); 3 ♂, 3 ♀, 6 juveniles, West Cape Howe National Park, 35°06’S, 117°37’E, 26 April 1990, M.S. Harvey, J.M. Waldock (WAM 98/1266-1277); 10 ♂, 8 ♀, 10 juveniles, West Cape Howe National Park, S. of Torbay Hill, 35°05’S, 117°38’E, 27 March 1993, M.S. Harvey, J.M. Waldock (WAM 98/1279-1307); 2 ♀, William Bay National Park, granite rocks at northern end of Petrified Forest, on sandy rocky scree, 35°01’S, 117°09’E, 26 May 1996, F. Malcolm (WAM 98/1308-1309).

DISTRIBUTION AND HABITAT

Based upon recently collected material lodged in the Western Australian Museum, we are able to present further locality records for this enigmatic species and make some observations on its distribution and ecology.

*Cynotelopus notabilis* appears to possess a very restricted range and the only available specimen-based records are from localities stretching along 115 km of the southern coast of Western Australia ranging from Tinglewood in the west, to Torbay Hill in the east (Figure 1). It has not been found at any other localities despite the careful examination of a wide range of moist habitats in south-western Australia over the past decade. Areas deliberately searched include Dog Pool on Shannon River (34°46’S, 116°22’E), Porongurups National Park (ca. 34°42’S, 117°53’E) and Stirling Range National Park (ca. 34°25’S, 118°00’E), sites that contain a plethora of relictual taxa. Mr Brad Maryan (Western Australian Museum) has informed us of a large population of *C. notabilis* at Mt Clare near Tinglewood, which was found in deep litter in unburnt forest in December 2000.

Sphaerotheriids are generally known from deep litter and under logs (Holloway, 1956; Jeekel, 1981), and our records include specimens from such habitats as well as under rocks. Specimens have been found under rocks associated with granite tors, from under logs and karri bark, and in leaf litter. On Torbay Hill *C. notabilis* readily colonises a garden adjacent to the bush and also pockets of disturbed, but unburnt, areas within the forest where it occurs under pieces of wood, debris and stones. The material collected from West Cape Howe National Park by MSH and JMW was found in very deep litter in a patch of mixed karri/redgum eucalypt/Allocasuarina decussata forest which clearly had remained unburnt for many years. The depth of the

Figure 1 Known distribution of *Cynotelopus notabilis* Jeekel in south-western Australia, based upon the specimens in the collections of the Western Australian Museum. Collection localities represented by solid circles.
litter and the lack of burning probably explains the high abundance of *C. notabilis* at this site which raises the distinct possibility that fire - both natural and human-induced - plays a significant role in the distribution of *C. notabilis*. Like many other millipedes, pill millipedes lack any significant dispersive stage and are vulnerable to localized extinction events, especially when the available habitat is severely disrupted by land clearing.

The bulk of the known range of *C. notabilis* occurs within the conservation estate of Western Australia, including three National Parks - Walpole-Nornalup, William Bay and West Cape Howe - but there are no available data on the persistence of populations after prescribed burns, which occur at frequent intervals in most Western Australian forests.

**ACKNOWLEDGEMENTS**

We gratefully thank Bob Mesibov for his thoughtful comments on a draft of the manuscript, Simon Judd for successfully searching for sphaerotheriids in south-western Australia, Jason Dunlop for searching for Western Australian sphaerotheriids in the Museum für Naturkunde der Humboldt-Universität (Berlin) collection, and Brad Maryan for alerting us to the Tinglewood population.

**REFERENCES**


Manuscript received 8 September 2000; accepted 7 March 2001.
Abstract - A new species of rynchonellid brachiopod, *Cirpa fromontae* sp. nov., is described from the Middle Jurassic Newmarracarra Limestone, Perth Basin, Western Australia. This is the first species of *Cirpa* recorded from Australia and links the region with the Tethyan Sea.

INTRODUCTION

The Newmarracarra Limestone was named after the historic “Newmarracarra” property. It is part of the Champion Bay Group and lies conformably between the Colalura Sandstone (shallow-marine unit of Bajocian age) or the Bringo Shale (Bajocian) and the Kojarane Sandstone (Bajocian) or the Yarragadee Formation (Late Jurassic to Early Cretaceous). The type section is at Round Hill (28°46'S, 114°48'E). Where unaffected by laterization, the Newmarracarra Limestone is sandy, “hard, massive and crudely bedded” (Playford et al. 1975). It is extensively weathered in parts. The thickest exposed section is 11.5 m thick on “Moonyoonooka” property, but the formation reaches 14.3 m at the Geraldton racecourse bore.

Rich invertebrate faunas including ammonites, annelids, belemnites, bivalves, bryozoans, foraminifers, gastropods, and ostracods have been recorded. One nautiloid and one echinoid have also been recorded (Playford et al. 1976). It is regarded as equivalent to the middle Bajocian of the Middle Jurassic having been deposited in a warm shallow sea (Playford et al. 1975).

Method and Material

The specimens are housed in the Invertebrate Palaeontological Collection of the Western Australian Museum (WAM). All measurements were made with dial callipers. The matrix was removed from specimens using dental tools. Where possible, the interiors were also cleaned of matrix. Serial sections were prepared by grinding on a glass plate using carborundum powder and sections were drawn using a camera lucida microscope.

Photographs were taken with a Nikon F 90 X camera with a macro lens and each specimen was prepared with a coating of ammonium chloride to whiten it for photography.

SYSTEMATIC PALAEONTOLOGY

Family Wellerellidae Likharev in Rzhonsnitskaya, 1956

Subfamily Cirpinae Ager, 1965

Genus Cirpa de Gregorio, 1930

Type species *Rhynchonella primitiva* Gemmellaro, 1874

*Cirpa fromontae* sp. nov.

1867 *Rhynchonella variabilis*; Clarke, p. 8.

1870 *Rhynchonella variabilis*; Moore, p. 231, 232, pl. X, fig. 11, 12.

1910 *Rhynchonella variabilis*; Etheridge Jr., p.30. pl. IX., fig. 3, 6.

1972 *Rhynchonella variabilis*; Skwarko, p. 60.


1992 *Burmirhynchia* sp.; McNamara and Brimmell, p. 10, fig. 35, 36.

Material Examined

Holotype

WAM 81.1396; Bringo Cutting, Newmarracarra Limestone, middle Bajocian, Middle Jurassic, Perth Basin, Western Australia.

Paratypes

WAM 63.84a, 66.98a, Waggrakine; WAM 74.885, Moonyoonooka; WAM 77.2280, north side of New Fossil Hill, Moonyoonooka; WAM 81.1499, 81.1943a and b, Bringo Cutting; Newmarracarra Limestone, middle Bajocian, Middle Jurassic, Perth Basin, Western Australia.
Figure 1  Map indicating the main sites of the Newmarracarra Limestone (after Hall 1989).

Other Material
WAM 65.1151, 8 km east of Moonyoonooka; WAM 62.191, 68.1240, 74.875, 77.2284, 95.333, Bringo Cutting; WAM 81.1369, 82.1055, Bringo siding, Bringo; WAM 96.388, 98.243, east part of Victoria Location, PT 2155, Bringo; WAM 92.679, Greenough River; WAM 78.4126, 81.1521, Mt Hill, Bookara; WAM 4968, 4971, 5009, New Fossil Hill; WAM 74.847, 77.2280, 82.8, 98.244, north side of New Fossil Hill, Moonyoonooka; WAM 4976, 4980, 4981, 4983, 4984, Round Hill; WAM 5025, 5037, south corner of Horse Hill; WAM 65.1220, 65.1225, 66.358, 82.10, 85.1116, 96.408, Waggrakine; WAM 65.1105, 65.1111, no locality; Newmarracarra Limestone, middle Bajocian, Middle Jurassic, Perth Basin, Western Australia.

Diagnosis
A species of Cirpa with a low blade like median septum in the brachial valve that bifurcates posteriorly, a rimmed foramen and impressed muscle scars.

Description
Exterior. Shell triangular to sub-pentagonal; length to 17.5 mm; widest at midlength (although some specimens length greatest at or near anterior), width to 110 % length. Biconvex, dorsal valve deepest, depth to 140 % of length in deepest of the specimens. Two varieties, one variety has flatter dorsal valves and the plication less pronounced. Growth lines indistinct except where costae high. Cardinal margin wide, strongly
New Jurassic brachiopod
Table 1

389

Measurement of Cirpa fromontae sp. nov. in millimeters.

Specimen
62.191
63.84
63.84
63.84a paratype
65.1111
65.1225
65.1225
65.1225
65.1225
65.1225
66.358
66.358
66.358
66.358
66.358
66.358
66.358
66.358
66.358
66.358
66.98a paratype
66.98
66.98
66.98
66.98
66.98
74.847
74.847
74.847
74.847
74.847
74.847
74.847
74.847
74.847
74.847
74.847
74.847
74.875
74.885 paratype
77.2280 paratype
78.4126
81.1369
81.1369
81.1369
81.1369
81.1396
81.1396a holotype
81.1493a paratype
81.1493b paratype
81.1499a paratype

Length

Width

Depth

13.4
10.0
16.0
17.8
14.3
4.5
9.2
10.6
11.8
15.2
5.0
5.7
7.4
8.6
10.5
10.9
11.1
13.0
16.0
17.5
9.4
5.8
10.9
11.2
13.5
14.7
9.3
9.4
9.6
10.1
10.7
10.9
11.0
11.5
11.5
11.7
13.3
13.9
13.1
17.0
15.0
14.6
11.7
13.1
13.1
14.1
10.7
16.1
5.5
13.6
9.9

14.1
12.4
11.2
18.0
14.2
4.4
9.2
10.1
12.5
15.5
4.9
6.3
7.4
8.5
7.6
12.0
10.2
14.3
11.8
19.1
8.4
5.8
12.3
10.5
14.8
11.6
10.7
9.4
10.3
10.0
11.6
10.2
10.7
11.7
10.7
12.7
12.3
14.3
16.0
18.7
15.1
17.5
12.4
15.2
13.2
15.5
12.1
16.2
7.9
13.2
10.1

8.5
10.2
11.8
10.7
13.3
1.7
3.7
7.0
5.5
10.0
1.3
2.1
2.9
2.4
4.6
7.5
7.2
9.0
11.6
12.8
2.1
4.7
6.5
9.0
7.4
5.4
4.9
8.7
6.3
7.4
5.1
6.1
6.9
7.2
9.0
9.9
5.7
8.8
10.6
6.2
9.6
6.5
7.9
11.4
13.5
6.5
10.1
-

curved; lateral valve edge rounded, margin
sigmoidal, anterior crenulate; anterior commissure
gently to strongly uniplicate, crenulate with two
plications in strongly uniplicate specimens to four
plications in weakly uniplicate specimens. Sulcus
in ventral valve commences just posterior of mid¬
length; fold in dorsal valve, where present,
commences at mid-length. Costae very sharp

Specimen
81.1499
81.1499
82.10
82.10
82.10
82.10
82.10
82.10
82.10
82.10
82.10
82.10
82.10
82.10
82.1055
82.1055
82.8
82.8
82.8
82.8
82.8
82.8
85.1116
85.1116
95.333
95.333
96.388
96.388
96.388
96.388
96.388
96.408
96.408
96.408
96.408
96.408
98.243
98.243
98.244
98.244
98.244
98.244
98.244
98.244
98.244
98.244
98.244
98.244
98.244
98.244
98.244

Length

Width

Depth

12.9
13.3
8.9
9.7
9.9
10.0
10.1
10.2
10.3
10.8
11.2
11.4
13.8
14.1
11.6
14.9
10.8
11.2
11.7
12.2
13.0
13.8
9.2
11.8
9.2
13.1
10.5
12.0
12.4
12.8
12.9
7.3
7.9
8.5
10.2
11.6
9.3
16.9
7.1
9.6
9.8
10.0
10.1
10.5
12.3
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12.8
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13.7
14.7

13.0
14.3
8.4
8.1
11.5
12.4
12.1
13.0
9.7
12.1
13.3
13.5
14.8
15.4
13.0
15.7
16.7
11.4
14.1
13.1
14.5
14.8
8.5
11.2
9.5
11.4
13.1
12.8
14.1
13.5
11.6
6.6
7.4
8.2
12.1
15.8
9.2
17.9
8.4
11.8
9.9
9.8
11.2
11.0
14.0
11.8
12.7
13.9
13.9
14.9
15.8

3.7
4.9
7.2
5.0
7.5
9.1
5.8
7.9
5.5
7.4
6.4
7.3
12.4
9.0
12.8
10.2
8.1
7.4
6.4
12.4
6.6
9.0
7.7
9.7
4.0
-

7.1
9.0
7.4
5.0
11.2
2.2
3.4
3.9
7.5
9.6
5.5
14.4
4.2
10.9
6.3
6.1
7.4
6.5
17.7
11.2
7.6
11.8
4.2
15.3
7.1

edged, varying in height to 23 % of shell length,
eight to twelve costae per shell with shallow
specimens with greatest number of costae. Costae
extend from posterior to anterior. Crenulate
pattern on margins irregular. Rugose. Beak short,
to 13 % shell length, erect to slightly incurved;
beak ridges sharp. Foramen oval to round to 10 %
shell length; mesothyrid. Deltidal plates triangular.


New Jurassic brachiopod

small, conjunct at apex. Symphytium high, narrow, concave. Well developed planareas.


Remarks

Clarke (1867) mentioned three species of rhynchonellid brachiopods from a "parcel of fossils" that he received from north of Champion Bay; there are no descriptions or attempts to name these specimens. He (Clarke 1867) did mention *Rhynchonella variabilis* Schlotheim 1813 in a group of fossils sent to Moore by Clifton. Moore (1870) listed *R. variabilis* and included a plate that is consistent with the above description. Etheridge (1910) described *R. variabilis* from Snake Farm, Greenough River as being biciplicate and triplicate. Ager (1959) noted that the name *Rhynchonella variabilis* has been applied to name a number of species from Europe and Asia. The species described above is not a *Rhynchonella* as it does not possess the sharp fold producing the cynocephalous shell form. The description of the Western Australian specimens in Etheridge (1910) is consistent with *Cirpa fromontae* sp. nov.

It is placed herein within the genus *Cirpa* as the morphological characteristics are most consistent with this taxon. The lack of a preserved cura prevents assigning a new genus.

Unlike other species of *Cirpa, C. fromontae* has a distinct median septum that extends to the mid-length and bifurcates slightly posteriorly in some specimens. It is low and blade-like. The rimmed foramen and impressed muscle scars are also distinctive. The specimens examined vary a great deal in depth and width but the number of costae is similar. Some specimens are flattened while others are distorted laterally (WAM 82.1055). One specimen is much shorter than wide possibly due to growth constraints (WAM 82.8a).

This species is unlike the rhynchonellids described by MacFarlan (1992) or the Antarctic species described by Quilty (1972). Campbell (1994) described a species of rhynchonellid brachiopod from the Late Triassic Rowley Terrace. He assigned it to *Trigonirhynchella. C. fromontae* is the only brachiopod species so far described from the Jurassic in Western Australia.

Etymology

The species is named in honour of Dr Jane Fromont, the Curator of Marine Invertebrates at the Western Australian Museum.

Conclusion

This is the first record of *Cirpa* from Australia. All previous species of the genus are from Europe and the Middle East. This links the Northern section of the Perth Basin with the Tethyan realm supporting Swarko’s suggestion of “sea connections between Western Australia and Europe and the Americas” (Swarko 1972 p 57). Distribution of the species across the Tethyan Sea may well have been by the attachment of larvae to seaweed or other drifting material such as pumice and wood. Wignall and Simms (1990) reported ‘*Rhynchonella subvariabilis* attached to a piece of drift wood from the lower Mutabilis Zone (Lower Kimmeridge Clay, Upper Jurassic) at Wyke Rigis, Weymouth, Dorset, United Kingdom.

Studies by Arkell (Arkell and Playford 1954) suggested the Western Australian ammonites have strong generic affinities with Europe and the west coast of America and the bivalves have similar affinities. However, at the species level, the majority of Newmarracarra taxa are endemic. This, with the new species of brachiopod described above, supports Skwarko’s (1972, p. 68) hypothesis that the Geraldton area was a “quiet embayment with limited access to outside influences”

ACKNOWLEDGEMENTS

I would like to thank the Western Australian Museum for the use of the collection and facilities to prepare this paper. I am grateful to G. W.

Figure 2  A-T *Cirpa fromontae* sp. nov. A-D, WAM 81.1396, holotype, A, ventral valve view, B, dorsal valve view, C, anterior commissure, D, lateral view, all x 2.9; E, WAM 81.1943a paratype, dorsal valve interior x 4.7; F, WAM 66.98 a, paratype, dorsal valve interior x 4.5; G, WAM 81.1499, paratype, ventral valve interior x 5; I, WAM 81.1943 b, paratype, ventral valve interior x 3.4; H, J-L, WAM 74.885, paratype, H, lateral view x 2.5, J, ventral valve view, K, dorsal valve view, L, anterior commissure (inverted), all x 2.6; M-P, WAM 77.2280, paratype, M, lateral view x 2.5, N, dorsal valve view x 3, O, ventral valve view x 3.4, P, anterior commissure x 2.6; Q, S, T, WAM 82.8a, Q, dorsal valve view x 2.5, S, anterior commissure x 2.7, T, lateral view x 2.6; R, WAM 63.84, paratype, dorsal valve x 2.4, showing lateral distortion.
Kendrick for reading the manuscript and offering suggestions for improvement. The constructive comments of D. A. B. MacFarlan and A. Wright were much appreciated.

REFERENCES


R. S. Craig


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Narcine lasti, a new species of numbfish from Western Australia and Indonesia (Chondrichthyes: Torpediniformes: Narcinidae)

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Abstract - Narcine lasti, n. sp., is described from abundant material mostly collected from the Western Australian coast. The new species is distributed from Green Head and the Houtman Abrolhos in the eastern Indian Ocean to southeastern Indonesia in the Arafura Sea, along the upper continental slope. Narcine lasti is distinguished by a unique combination of characters including a tail length much longer than disc width or length, uniform yellowish-brown to yellowish-pink dorsal colouration that also extends anteriorly over preorbital snout region, lateral tail folds low and ridge-like, disc width and length with means of 40.3 and 42.1 % of total length (TL) respectively, nasal curtain much wider than long, and preorbital snout length over 10 % of TL. Narcine lasti is most similar to N. tasmaniensis and another undescribed species of Narcine from off the Queensland coast of Australia. All three species have relatively similar proportions and dorsal colouration, but can be distinguished on the basis of preorbital snout length, disc width and length, lateral tail fold morphology and usually also in dorsal colouration. Narcine lasti is easily distinguished from Narcine westraliensis McKay, 1966, the only other species of the genus in Western Australia, by many features including disc shape, relative proportions of the tooth bands, and in dorsal colouration. Both species do not co-occur, as N. westraliensis is distributed on the continental shelf in relatively shallow waters, while N. lasti is confined to deeper waters of the continental slope.

INTRODUCTION

The chondrichthyan fauna of Australia is one of the most diverse in the world with as many as 300 species, an estimated one-third of which is still undescribed (Last and Stevens, 1994; Last and Séret, 1999). Systematic studies of Australian chondrichthians have progressed at a relatively slow pace since G. P. Whitley’s classic review (Whitley, 1940). This situation was dramatically changed by the publication of “Sharks and Rays of Australia” by Last and Stevens (1994), with descriptions and much information concerning all Australian chondrichthians, accompanied by excellent colour illustrations of all species. Last and Stevens (1994) reported five species of the torpediniform genus Narcine Henle, 1834 from Australia, three of which were treated as undescribed.

In conducting revisionary studies of electric ray genera, the senior author examined numerous specimens of an undescribed species of Narcine present off the coast of Western Australia (Carvalho, 1999a). Specimens of this undescribed form were first collected in 1978, but due to extensive sampling mostly on the R/Vs Soela, Southern Surveyor and Invincible in the 1980s and early 1990s, abundant material is now available in Australian collections. Additional specimens of this new species were collected by the junior author from two proximal localities in 1991 during the exploratory cruise “Karubar,” trawling off southeastern Indonesia. We describe below this new species, which corresponds to “Narcine sp. B” of Last and Stevens (1994) and “Narcine sp. nov. B” of Carvalho (1999a).

Electric rays of the genus Narcine (“numbfishes” or “lesser electric rays”) are usually small to medium-sized batoids, occurring in tropical to subtemperate waters in most major oceans (Bigelow and Schroeder, 1953). They are conspicuously absent from the Mediterranean and Red seas, the west African coast, New Zealand, Pacific Plate islands, and regions predominantly influenced by cold water currents. They are more common on continental shelf or upper slope areas, and are believed to have a relatively low mobility (e.g.
Rudloe, 1989). Narcine is distinguished from the other nine valid electric ray genera by a unique combination of characters, including two dorsal fins, a prominent circumanal groove, stout labial cartilages, expanded trough-shaped rostrum, branching antorbital cartilages, tooth bands extending onto the external oral integument, functional eyes, and posteriorly separated pelvic fins (Bigelow and Schroeder, 1953; Compagno, 1973; Carvalho, 1999a). Carvalho (1999a) revised the genus, recognising 20 valid species, nine of which were undescribed. The species description presented here is done in advance of the forthcoming publication of the generic revision by the senior author.

MATERIALS AND METHODS

Comparative material of all species of Narcine was used for the present description, and is listed in Carvalho (1999a). Non-type material of the new species is listed at the end of this paper. Institutional abbreviations follow Leviton et al. (1985). Measurements were taken in a straight line, from point to point, using electronic callipers to the nearest tenth of a millimetre, following the methods established in Carvalho (1999a) for narcinid electric rays. Specimens greater than 150 mm were measured with steel ruler or with a tape measure, and are expressed to the nearest millimetre. Measurements were conducted on specimens in order to obtain proportional morphometric characters useful for descriptive and identification purposes, but certain caution is warranted when specimens appear damaged, dehydrated or distorted from their original state, which may be common with electric rays (French and McEachran, 1984; Carvalho, 1999b). All measurements are presented in Table 1, and are expressed as proportions of total length in order to be readily available for comparisons. Measurements are as follows: total length (TL, in millimetres; independent variable from which all proportional values are derived); disc width (DW, across widest aspect of disc, usually close to level of third gill openings); disc length (DL, from anterior snout region to greatest disc length, lateral to pectoral axil); preorbital snout length (PBS, from in between anterior level of eyes to anterior margin of snout); preoral snout length (POS, from top of lower tooth band to anterior margin of snout); prenasal snout length (PNS, from in between anterior level of nostrils to anterior margin of nostrils); snout to greatest disc width (SDW, from anterior snout to level of greatest disc width, measured over mid-disc); interorbital distance (IOD, straight distance between inner margins of orbits); eye length (EL, between anterior and posterior margins of eye); interspiracular distance (ISD, between inner margins of spiracles); spiracle length (SPL, greatest antero-posterior distance through spiracle); spiracle width (SPW, greatest lateral extent of spiracle); mouth width (MW, distance between mouth corners, measured between junction of upper and lower labial cartilages of each side of jaws); upper tooth band width (UTB, width of exposed upper tooth band in between posterior margin of lips [formed by the upper labial cartilages], close to mouth opening); lower tooth band width (LTB, width of exposed lower tooth band at anterior margin of lips [formed by the lower labial cartilages], close to mouth opening); nasal curtain width (NCW, width of nasal curtain at greatest width below nostrils); nasal curtain length (NCL, length of nasal curtain from level of anterior margin of nostrils to posterior-most point at mid-line of nasal curtain); distance between nostrils (DBN, between inner margins of nostrils); distance between first gill openings (FGO, between inner margins of first pair of gill openings); distance between last gill openings (LGO, between inner margins of last pair of gill openings); branchial basket length (BBL, between first and last gill openings); pelvic fin length (PFL, length of pelvic fin from insertion to posterior-most point, measured ventrally); pelvic fin width (PFW, distance between outer-most corners of pelvic fins, from tip to tip, measured ventrally); anterior margin of pelvic fin (AMP, greatest extent from outer-most corner to posterior-most point of pelvic fin); tail width (TW, extent across base of tail at greatest width, measured dorsally); height of first dorsal fin (HFD, distance from greatest height at apex to mid-base of first dorsal fin); length of first dorsal fin (LFD, greatest length of base of first dorsal fin); height of second dorsal fin (HSD, distance from greatest height at apex to mid-base of second dorsal fin); length of second dorsal fin (LSD, greatest length of base of second dorsal fin); length of dorsal lobe of caudal fin (LDC, distance from origin on dorsal caudal peduncle to posterior-most tip of caudal fin); length of ventral lobe of caudal fin (LVC, distance from origin on ventral caudal peduncle to posterior-most tip of caudal fin); height of dorsal lobe of caudal fin (HDC, measured vertically from upper-most tip of caudal fin apex to base of dorsal lobe on tail); height of ventral lobe of caudal fin (HVC, measured vertically from lower-most tip of caudal fin to base of ventral lobe on tail); height of caudal fin (HC, greatest distance between dorsal and caudal fin margins, does not equal HDC + HVC); distance between dorsal fins (DBD, distance between posterior tip of first dorsal fin base and anterior tip of second dorsal fin base); distance between second dorsal fin and caudal fin (SDC, from posterior tip of second dorsal fin to dorsal origin of caudal peduncle); distance between
New species of numbfish

Order Torpediniformes Berg, 1940
Family Narcinidae Gill, 1862
Narcine Henle, 1834

Diagnosis
Narcinid electric rays distinguished from the other three genera of the family {Discopyge Heckel, 1846, Benthobatis Alcock, 1898 and Dipllobatis Bigelow and Schroeder, 1948} by the following unique combination of external features: joint nasal curtain with straight posterior margin, without median posterior flap (present in Discopyge); pelvic fins separated posteriorly, not joined to form “apron” (present in Discopyge); eyes functional and clearly visible externally anterior to spiracles, usually about same size or slightly larger or smaller than spiracles (eyes externally not readily visible in Benthobatis); nostrils are a single opening, not subdivided into two distinct compartments by bridge of stiff integument between dorsal nasal curtain and ventral nasal flaps (nostrils fully divided in Dipllobatis); claspers adjoined latero-externally to pelvic fins, not covered and concealed dorsally by pelvic fins (condition in Dipllobatis and some species of Benthobatis); both lower and upper tooth bands remain exposed on external oral integument when mouth is closed (tooth bands not readily exposed in Benthobatis and Diplobatis; lateral tail folds or ridges on lateral aspect of tail generally well developed, extending from level of first dorsal fin posteriorly to caudal peduncle (Benthobatis has rudimentary lateral tail ridges). The following anatomical features are hypothesised as supporting the monophyly of Narcine (Carvalho, 1999a): fused and paired hypobranchial plates with sinuous external margins, articulating with ceratobranchials 2-4; facio-palatine foramen present within the orbit; conspicuous heart-shape of basibranchial copula that bears a well-developed, slender posterior process; lack of contact between ceratohyal and the component tentatively identified as being the first hypobranchial.
Narcine lasti, new species
Figures 1-7, Tables 1-2

Narcine sp.: Sainsbury et al., 1985: 44, 330 (brief comparison, listed).
Narcine sp. B: Last and Stevens, 1994: 376, plate 66, figure 39.2 (identification, description, distribution, illustrated in colour); Williams et al., 1996: 144 (listed); Carvalho et al., 2000: 1441 (identification, distribution, illustrated).
Narcine sp. nov. B: Carvalho, 1999b: 219-226, figures 77-81 (diagnosis, description, distribution, illustrated, colour photographs).

Holotype
CSIRO H1036-03, 325 mm TL adult female, from north of Cape Lambert (Western Australia [WA]) at 19°06'S, 117°08'E, 178–183 m, FRV Soela, S07-87-129, 12 October 1987. Figure 1.

Paratypes
21 specimens total (115-365 mm TL)–AMS I 31174-010, 234 mm TL pre-adult male (almost adult), off Shark Bay (WA), 26°42.3'S, 112°38.4'E–26°42.1'S, 112°38.5'E, 285 m, FRV Southern Surveyor, 30. January 1991; CSIRO H1035-01, 331 mm TL adult female, from north of Dampier archipelago (WA), 19°08'S, 116°54'E, 196–198 m, FRV Soela, S06-86-84, 24 October 1986, CSIRO H1035-02, 330 mm TL adult female (data as in H1035-01); CSIRO H1035-03, 272 mm TL adult male (data as in H1035-01); CSIRO H1036-01, 325 mm TL adult female (data as in holotype); CSIRO H1036-02, 312 mm TL pre-adult or adult female (data as in holotype); CSIRO H2597-08, 365 mm TL adult female (Figure 2), from west of Green Head (WA),

Figure 1 Dorsal (A) and ventral (B) views of holotype of Narcine lasti, n. sp., (CSIRO H1036-03, 325 mm TL adult female); from north of Cape Lambert, WA, 19°06'S, 117°08'E, 178–183 m.
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Figure 2 Paratypes of *Narcine lasti*, n. sp.: A) dorsal view of CSIRO H2597-09 (mature male, 302 mm TL); B) and C) dorsal and ventral views respectively of CSIRO H2597-08 (adult female, 365 mm TL); both specimens from west of Green Head (WA), 29°59’S, 114°28’E, 265 m.

29°59’S, 114°28’E, 265 m, FRV Southern Surveyor, SS 0191/63, 8 February 1991; CSIRO H2597-09, 302 mm TL adult male (Figure 2) (data as in H2597-08); CSIRO H3222-06, 315 mm TL adult female, north of Dampier archipelago (WA), 19°12’S, 116°25’N, 190 m, FRV Southern Surveyor, SS 2/90/136, 11 October 1990; CSIRO H4070-06, 256 mm TL pre-adult male, from northwest of Port Hedland (WA),
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Figure 3  Dorsal (A) and ventral (B) view of paratype of Narcine lasti, n. sp., MNHN 1996-1556 (302 mm TL adult female from the Arafura Sea, off Tanimbar Island, Indonesia, 9°01'S, 132°42'E, 246–253 m).

18°12'S, 118°14'E, 269 m, FRV Southern Surveyor, SS 8/95/123; CSRIO H4070-07, 244 mm TL pre-adult female (data as in H4070-06); CSRIO H4070-08, 250 mm TL pre-adult male (data as in H4070-06); MNHN 1996-1556 (3 specimens), 302 mm TL adult female (Figure 3), 190 mm TL juvenile male, 115 mm TL juvenile male, from off Tanimbar Island (Indonesia), 9°01'S, 132°42'E, 246–253 m, cruise “Karubar,” sta. CP62, 1 November 1991; NMV A1798 (2 specimens), 305 mm TL adult female, 270
New species of numbfish

mm TL adult male, southwest of Shark Bay (WA), 27°07'S, 112°49'E-27°01'S, 112°48'E, 238-248 m, R/V Hai Kong, 3 March 1981; WAM P26208-025 (4 specimens), 261 mm TL adult male, 241 mm TL pre-adult, 232 mm TL pre-adult male, 231 mm TL pre-adult male, 225 km NNW of Port Hedland (WA), 18°22'S, 118°03'E, 258-270 m, R/V Courageous (J. Barry Hutchins), shot 0693, 20 May 1978.

Diagnosis

A species of Narcine from the eastern Indian Ocean and Arafura Sea diagnosed by the following unique combination of characters: tail length as measured from cloaca much longer than disc width or length (tail length with a mean of 53.7 % of TL, compared to means of 40.3 % of TL for disc width and 42.1 % of TL for disc length); nasal curtain much wider than long; uniform light yellowish-brown dorsal colour pattern, which is also present over preorbital snout region, and without any distinctive spotting or other markings over disc and tail; low and inconspicuous lateral tail ridge, not resembling a distinct fold; mean preorbital snout length just over 10 % of TL.

Table 1 Measurements for Narcine lasti, n. sp. N is number of specimens from which means and standard deviations (SD) were taken, and includes type and non-type specimens. Holotype: CSIRO H1036-03. Paratypes (excludes 2 specimens from MNHN 1996-1556, 190 and 115 mm TL juvenile males, and all four WAM P26208-025 specimens): AMS I 31174-010, CSIRO H1035-01, H1035-02, H1035-03, H1036-01, H1036-02, H2597-08, H2597-09, H3222-06, H4070-06, H4070-07, H4070-08, MNHN 1996-1556 (302 mm TL female), NMV A1798 (2). See material and methods section for explanation of acronyms.

| TL (mm) | DW (%) | DL (%) | PBS (%) | POS (%) | PNS (%) | SDW (%) | IOD (%) | EL (%) | ISD (%) | SPL (%) | SPW (%) | MW (%) | UTB (%) | LTB (%) | NCW (%) | NCL (%) | DBN (%) | FGO (%) | LGO (%) | BBL (%) | PFL (%) | PFW (%) | ALP (%) | PLP (%) | TW (%) | HFD (%) | LFD (%) | HSD (%) | LSD (%) | LDC (%) | LVC (%) | HDC (%) | HVC (%) | HC (%) | DBD (%) | SDC (%) | SCL (%) | CLC (%) | SFD (%) | EOL (%) | EOW (%) | CL (%) |
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Description

Measurements and counts are summarised in Tables 1 and 2, respectively.

*External morphology* - Disc slightly oval in some specimens, generally longer than wide (disc length is 38.2 to 48.6 % of TL, disc width is 34.1 to 45.2 % of TL), and distinctively shovel-shaped in most preserved specimens. Disc widest relatively posteriorly close to pectoral fin insertion, at posterior one-fourth or one-fifth of its length in adults, and at around one-sixth in juveniles. Disc just barely overlaps origin of pelvic fins at its posterior aspect, and does not leave a prominent free lobe posteriorly. Snout rounded but may be slightly angled in some preserved specimens. Preorbital snout length about one-tenth of total length, and about one-third of disc length. Electric organs not clearly visible dorsally, more conspicuous in juveniles. Electric organs originate just anterior to level of eyes dorsally and continue posteriorly to about five-sixths of disc length; ventrally electric organs originate just posterior to level of nostrils. Electric organ length between 16.7 to 24.0 % of TL, and width between 5.0 and 9.4 % of TL. Gill slits semi-circular, small and positioned more or less in a straight line from first to last gill slit. Distance between last gill slits and branchial basket length about equal. Spiracles separated from eyes by a small gap in juveniles, but gap reduced in adults; spiracles without strongly elevated rims but with rounded posterior margins. Spiracle length and width about equal. Pseudobranchials folds present inside anterior

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Table 2 Counts for *Narcine lasti*, n. sp. A) CSIRO H1036-01 (paratype); B) CSIRO H2597-09 (paratype); C) MNHN 1996-1556 (paratype); D) NMV A9656; E) NTM 13579-004; F) NTM 12641-021; G) CSIRO 4367; H) NMV A1798 (paratype); I) NMV A1798 (paratype); J) NTM 13578-009. Dashes represent counts not available in radiographs. See material and methods section for explanation of acronyms.

Figure 4 Illustration of *Narcine lasti*, n. sp., in dorsal perspective (from Carvalho et al., 2000; used with permission from FAO).
New species of numbfish

A) Lateral tail region of holotype (CSIRO H1036-03) of *Narcine lasti*, n. sp., showing distribution of lateral tail pores, lateral tail ridge, and relative positions of pelvic and dorsal fins; B) ventral snout region of holotype showing arrangement of external tooth bands and nasal curtain; C) external morphology of left clasper (compiled from various specimens). Abbreviations: AP, apopyle; CG, clasper groove; DPS, dorsal pseudosiphon; HP, hypopyle; PF, pelvic fin; VPS, ventral pseudosiphon. Scale bar = approximately 15 mm.

| spiracular wall (eight within each spiracle in paratype MNHN 1996–1556; the same amount present in other specimens, e.g. MNHN 1996–1557). The individual pseudobranchial fold located farthest toward mid-line situated deeper within the spiracle. Eyes slightly bulging, longer than wide and longer than spiracles, and faintly darker than background disc colour.

Nasal curtain wider than long (Figure 5B), with straight posterior margin in most specimens, but a small central posterior lobe may be present in well-preserved material. Nasal curtain projects slightly laterally posterior to nostrils, giving it a faint trilobed appearance. Nostrils very circular with slightly elevated, wide rims. Prenasal snout length almost equal to preorbital snout length (in relation to total length, averaging close to 10 % of TL). Sensory pores on ventral snout region (Figure 5B) do not continue posteriorly to level of nostrils. Mouth generally only slightly wider than distance between outer nostrils. Upper tooth band wider than lower tooth band, fairly circular in outline. Lower tooth band may be more acute in outline appearing sub-triangular in some specimens. Teeth in 11/8–20/15 exposed vertical rows in pre-adults and adults (a typical adult of more than 300 mm in total length will have about 19/15 rows). Teeth in quincunx arrangement, with trapezoidal or diamond-shaped crowns, slightly wider than long. Cusps relatively long, especially on more inner rows, but more exposed teeth have cusps considerably more worn. |
Pelvic fins when measured together wider than long, with longer posterior rather than anterior margins, and with a small free lobe posteriorly. Pelvics extend caudally from just underneath disc to just anterior to level of origin of first dorsal fin on tail. Pelvics somewhat rounded laterally, with fleshy lateral corners. In adult males, claspers relatively slender and elongated. Claspers in mature males project to about one-fifth of their total length beyond tips of pelvics, reaching close to one-half of first dorsal fin base length. Clasper groove inflects somewhat abruptly towards mid-line close to its mid-length between apopyle and hypopyle, and continues to terminate close to clasper distal tip (Figure 5A). Both dorsal and ventral pseudosiphons present, but ventral pseudosiphon relatively straight and clearly longer than dorsal pseudosiphon; dorsal pseudosiphon curved, wrapping slightly around internal margin of clasper. Tail long, ranging from 50.0 to 57.1 % of TL as measured from cloaca, but not very broad at base (mean is 16.5 % of TL). Tail sub-circular in cross section. Tail not tapering greatly from base to second dorsal fin, but tapering more from second dorsal to caudal fin. Lateral tail ridges not prominent, difficult to discern in some specimens, and appearing only as a low ridge (not a fold or flap). Lateral tail ridge beginning underneath level of first dorsal fin base, from origin to mid-base level in well-preserved specimens, inserting on lateral aspect of caudal peduncle close to its ventral margin (Figure 5A). First dorsal fin originates at a relatively posterior position on tail, generally behind apex of pelvic fins. Dorsal fins slightly rounded to sub-acute at apex, with sloping anterior and curved posterior margins. Dorsal fins insert on tail leaving a small free lobe posteriorly. Both dorsal fins very similar in size and shape, but second dorsal usually more slanted. Distance between second dorsal and caudal fin generally greater than distance between dorsal fins. Caudal fin low and moderately long (reaching to approximately 13 to 14 % of TL), with relatively straight posterior margin. Height of caudal fin, as measured with both upper and lower lobes together, about equal to height of dorsal fins. Lower lobe of caudal fin begins just anterior to level of origin of upper caudal fin lobe in some larger specimens.

As in all Australian species of Narcine, pores of the lateral-line and ampullary systems very difficult to observe and identify on both dorsal and ventral surfaces without more specific preparation. Few pores of the lateral canal present on the lateral tail region; these just dorsal to the lateral tail ridges (Figure 5A), continuing caudally beyond the level of caudal peduncle to terminate on the caudal fin tip at its mid-height. Very few scattered pores present of the hyomandibular and scapular canals outlining electric organs dorsally (ampullary pores outlining electric organs ventrally also present). Ampullary pores on ventral snout region in two relatively straight antero-posterior rows, with the last pores of each row somewhat laterally displaced (Figure 5B). Pores do not continue far posterior of level of anterior margins of nostrils. Two small group of pores anterior to each nostril on ventral snout area, and one pair of inconspicuous endolymphatic pores present posterior to eyes at mid-line.

**Colouration** – Dorsal colouration in preservative usually pale yellow to light tan or faded beige. Freshly caught specimens may be yellowish-pink over disc and tail (perhaps due to internal haemorrhaging). Specimens have a very uniform colour dorsally, with areas of slightly lighter intensity over pelvic fin margins, anterior region of pelvic fins, and at lateral tail base regions. Dorsal and caudal fins semi-transparent posteriorly. In preserved specimens, dorsal colouration may seem even lighter, but always a yellowish beige or tan. Ventrally specimens are a pale white to cream colour, devoid of more distinctive markings.

**Skeletal anatomy** – Skeleton calcified throughout, but superficial calcification particularly developed over neurocranium (especially at occipital condyles), synarcal, scapulocoracoid, pelvic girdle and pectoral fin-base. Neurocranium elongated, its length about one-half of disc length, and relatively massive anteriorly with a stout rostrum (Figure 6). Rostrum widest anteriorly, tapering strongly toward nasal capsules, and about one-half of total neurocranial length. Lateral rostral cartilages, as in *N. brasiliensis*, absent (this may be an artefact of radiography), but there is support lateral to rostral fontanelle as rostrum resembles a spatula anteriorly (LP, Figure 6A). Rostrum very wide lateral to rostral fontanelle, almost as wide as greatest neurocranial width at nasal capsules. Strong notch present anteriorly on each side of rostral lateral to rostral fontanelle. Rostral fontanelle conspicuously longer than wide and relatively small, with a somewhat straight anterior contour, and resembling basibranchial copula typical of *Narcine* with a posterior notch close to the precerebral fontanelle. Precerebral fontanelle long, relatively wide and rectangular in general configuration. Lateral rostral fenestrae somewhat obscured in radiographs but appear to be present on both sides of rostrum. Basonasal fenestrae typically absent. Nasal capsules articulate laterally with well-developed antorbital cartilages. Antorbitals cartilages relatively stout at bases, expanding distally to form extensive ramifications (but not as much as in *N. brasiliensis*). Antorbitals subdivided at about one-third of their total length, where small foramina are present, and where there is a slender, but relatively elongated posterior projection. Posterior extension of antorbitals at disc margin greater than the anterior
Figure 6 Radiographs of *Narcine lasti*, n. sp., showing aspects of its skeletal morphology. A) NTM 13579-004 (Arafura Sea, NT; anterior disc showing neurocranium and jaws only), and B) CSIRO CA 2597 (from off Green Head, WA; disc and anterior aspect of pelvic fins). Abbreviations: ANT, antorbital cartilage; EO, electric organ; HYO, hyomandibula; LP, lateral process of rostrum; MES, mesoptrygium; PF, precerebral fontanelle; PRO, propterygium; RF, rostral fontanelle; RO, rostrum. Scale bar = 15 mm.
antorbital segment. Orbits occupy about one-third of total neurocranial length. Otico-occipital segment relatively short and slender. Frontoparietal fontanelle and parietal fossa obscured in radiographs. Lateral knob-shaped process ventral to articulation with hyomandibulae present but not as pronounced as in *N. brasiliensis.*

Jaws stout, mandibles more robust than palatoquadrate. Both sets of jaws not fused medially and taper toward mid-line. A stout dorsal projection present laterally on each mandible. Two pairs of slender and triangular labial cartilages, one anterior to each jaw, forming “lips” that surround tooth bands. Hyomandibulae stout at bases, tapering toward jaw corners, and articulating strongly with otic region of neurocranium (Figure 6). Hyomandibulae articulate through strong ligaments distally with lower jaws for about one-third of their length. Slender prepyrapiacal cartilages at posterior ends of hyomandibulae, projecting at right angles, and supporting anterior wall of spiracle. A pair of “palatine” cartilages visible in radiographs at level of lower jaws. Pseudohyoid arch (composed of both dorsal and ventral elements) slender and inconspicuous, situated over posterior end of hyomandibulae, “wrapping” around it. Gill arches typically not wide (as in all electric rays, due to electric organs). The first and second gill arches articulate with neurocranion posterior to hyomandibulae. Both cerato- and epibranchial elements have central depressions or fossae for the insertion of depressor muscles. Last ceratobranchial morphologically distinct, being more slender and posteriorly oriented to articulate with scapulocoracoid. Pharyngobranchials small and slender, and somewhat posteriorly oriented. Pharyngobranchials contact synarcual distally (not all pharyngobranchials visible). Hypo- and basibranchial elements not discernible.

Synarcual with three and one-half vertebral centra in its posterior segment, and twelve pairs of spinal nerve foramina anterior to the first centrum. Triangular lateral stays with slightly sloping anterior margins at anterior to mid-synarcual length. Coracoid bar relatively slender in dorso-ventral view. Suprascapula also slender and articulate with scapular processes laterally. Scapulae stout, extending posteriorly, with two condylar projections present distally for articulation with pectoral pterygia (one for the propterygium and one for both the meso- and the very inconspicuous metapterygium; Figure 6B). At least three pairs of foramina present on lateral aspect of the scapular process, with a large fossa also present anteriorly on the scapulae. Propterygium divided into five segments, largest segment most basal, and almost same length as other propterygial segments combined. External margin of propterygium slightly sinuous to articulate with radials. Propterygium expanded at its base, contacting mesopterygium. Mesopterygium slender, projecting anteriorly to about one-third of length of most basal propterygial segment. Metapterygium also slender, weakly calcified and generally obscured in radiographs. Pectoral radials divided into at least four unbranched, weakly calcified segments. Pelvic girdle slender with a concave anterior margin. Pre-pelvic process elongated on each corner of girdle, extending anteriorly to almost level of scapulocoracoid (Figure 6B). A small, curved and slender iliac process present at each corner of pelvic girdle, projecting dorsally. At least three foramina present at corners of puboischiadic bar. First pelvic radial element characteristically enlarged, pelvic radials generally stout and segmented only distally (at least three segments present). Basipterygium has a sinuous external margin where it articulates with radials. Ribs present anterior to pelvic girdle and continue caudally to just posterior to it. Both dorsal fins internally similar, without enlarged basal elements. Dorsal fins have closely set radial segments. Dorsal radials of the caudal fin begin at fin origin, but elongated haemat arches present anterior to caudal fin origin. Caudal dorsal radials more slender than ventral radials. Vertebras strongly calcified and articulate posteriorly with distal-most caudal radial.

Etymology

The specific epithet *lasti* is a patronym in honour of friend and colleague Dr. Peter R. Last, in recognition of his studies on the taxonomy and distribution of Australian elasmobranchs.

Geographical distribution

*Narcene lasti* has a wide distribution, occurring in the Arafura Sea (southeastern Indonesia, south of Tanimbar Island; also off the Northern Territory, Australia) and extending southwest along the continental slope of Australia as far south as off Green Head, Western Australia (Figure 7). *Narcine lasti* has been found in depths ranging from 178 to 333 m, predominantly over sandy and muddy bottoms.

**DISCUSSION**

Comparisons with congeners

This species was first reported by J. B. Hutchins in an unpublished report to CSIRO in 1979 (as *Narcine sp.*). Gloerfelt-Tarp and Kailola (1984) were the first to mention it subsequently, in a survey of trawled fishes of Indonesia and northwestern Australia. It was listed as “*Narcine sp. 1*” and has been suspected of being a new species for more than a decade, but only recently was it characterised in any detail (Last and Stevens, 1994; Carvalho, 1999a).
The identification of *Narcine lasti* is usually quite straightforward. All other species of *Narcine* have a tail length less than or subequal to disc width and length, except *N. rierai* (Lloris and Rucabado, 1991) and the Australian species of *Narcine* (*N. tasmaniensis* Richardson, 1841, *N. westraliensis* McKay, 1966, and *Narcine* sp. nov. A and *Narcine* sp. nov. C sensu Last and Stevens, 1994, Carvalho, 1999a, and Carvalho et al., 2000). From *N. rierai*, *N. lasti* is distinguished by having a nasal curtain that is much wider than long (nasal curtain is diagnostically longer than wide in *N. rierai*; Lloris and Rucabado, 1991; Carvalho, 1999a). From *N. westraliensis* and *N. sp. nov. A*, *N. lasti* is distinguished by having a uniform yellowish-brown dorsal colour pattern without any specific spotting or other distinctive markings (*N. westraliensis* has horizontal irregular stripes over disc and tail, and *N. sp. nov. A* has large spots surrounded by smaller spots over disc and tail; McKay, 1966; Carvalho, 1999a). Many other features in addition to colour pattern separate our new species from *N. westraliensis*: size and arrangement of tooth bands (tooth bands relatively wider in *N. westraliensis*, with means of 2.6 and 2.1 % of TL for upper and lower tooth bands, respectively), shape of disc (more rounded in *N. westraliensis* compared to shovel-shaped in *N. lasti*), which is reflected in the distance between snout and greatest disc width: the mean in relation to TL is 26.6 % in *N. westraliensis* compared to 32.1 % in *N. lasti*).

From *N. tasmaniensis*, *N. lasti* is distinguished by having a low, ridge-like lateral tail fold (the lateral tail fold is more broad and flap-like in *N. tasmaniensis*), a relatively more slender disc (disc width with a mean of 40.3 % of TL in *N. lasti*, compared to a mean of 43.4 in *N. tasmaniensis*), a greater preorbital snout length (mean is 10.1 % of TL in *N. lasti*, compared to 7.8 in *N. tasmaniensis*) and by a lighter dorsal colouration (usually a dark chocolate brown in *N. tasmaniensis* as opposed to yellowish brown in *N. lasti*; Carvalho, 1999a).

*Narcine lasti* is distinguished from *Narcine* sp. nov. C by presenting a relatively wider and longer disc.

Figure 7  Distribution of *Narcine lasti*, n. sp. Closed circles may represent more than one locality. Star indicates original location of holotype.
(with means of 40.3 and 42.1 % of TL, respectively, in N. lasti, compared to means of 38.4 and 40.2 % of TL in N. sp. nov. C), and by having a light yellowish-brown background (extending into preorbital snout region) compared to, in N. sp. nov. C, a slightly darker uniform brown background colour with a preorbital snout region distinctly lighter in many specimens. Carvalho (1999a) also documents differences among these two species in numbers of tooth rows, distance between dorsal fins and possibly size at maturity. Furthermore, Narcine lasti and Narcine sp. nov. C are entirely separated geographically, the former occurring off the Western Australian coast and in the Arafura Sea, while the latter is restricted to relatively deep waters off the Queensland coast. However, both species are very similar in overall aspect sharing a relatively long tail and shovel-shaped disc, and together with Narcine tasmaniensis appear to form a species-group (Carvalho, 1999a).

Comments on sexual maturity
Judging from clasper rigidity, sexual maturity for males appears to occur at around 240 mm TL, as a 234 mm TL male examined is close to being sexually mature (assuming that sexual maturity closely follows clasper rigidity, as is usually the case in electric rays). However, a few examined male specimens larger than 265 mm TL have somewhat “soft” claspers, but appear to be very close to sexual maturity, if not already capable of reproduction (one specimen of 297 mm TL with relatively soft claspers was also examined). Sexual maturity for females putatively occurs at similar sizes. A 331 mm TL female was found to contain two late-term embryos, one in each uterus, as well as one large egg mass without an associated visible embryo in the right uterus. The late-term embryos measured 72 and 77 mm TL (consisting of a male and female specimen, respectively), both with yolk-sacs and yolks-staiks still attached, but were undoubtedly close to birth. Egg masses were found in both uteri in other large females that also contained late-term pups, corroborating that both uteri are functional and synchronous in N. lasti. The uteri of females of N. lasti are extremely thin-walled and somewhat transparent, apparently without any nutrition-supplying function.

Non-type material examined (48 specimens, 75-361 mm TL)
Western Australia - AMS I 22821-007 (5), 204 mm total length juvenile male and 227 to 255 mm total length pre-adult females, 18°16'S, 118°12'E, 320 m, FRV Soela, J. Paxton, 10 April 1982; CSIRO CA327, 198 mm total length pre-adult female; CSIRO CA330, 360 mm total length adult female, “Northwest Shelf, WA,” FRV Courageous, v. 1978; CSIRO CA347, 245 mm total length pre-adult male; CSIRO H 1035 (2), 2 late-term embryos extracted from uteri of 331 mm total length female (H1035-01), each approximately 75 mm in total length (not measured further; data as in paratype H1035-01; CSIRO CA1486, 206 mm total length pre-adult male; CSIRO H2547-10, 321 mm total length adult female, from west of North West Cape, 21°37'S, 113°59'E, 209-215 m, FRV Southern Surveyor, SS 0191/7, 24 January 1991; CSIRO CA2812, 298 mm total length adult female, from north of Forester Island, 18°10'S, 118°20'E, 300 m, FRV Soela, sta. 2/82/36, 10 April 1982; CSIRO CA2813, 258 mm total length pre-adult female (data as in CA2812); CSIRO CA2873, 315 mm total length adult female, from north of Forester Island, 18°31'S, 118°09'E, 200 m, FRV Soela, sta. 2/82/14, 2 April 1982; CSIRO H3054-03 (3), 361 mm total length adult female with 2 late-term embryos (not measured), from north of Carnarvon, 24°40'S, 113°43'E, 225 m, 28. ix. 1990; CSIRO H4031-81, 117 mm total length pre-adult male, from northwest of Port Hedland, 18°12'S, 118°14'E, 269 m, SS 8/95/123; CSIRO CA4361, 216 mm total length pre-adult female, from north of Port Hedland, 18°11'S, 118°16'E, 304 m, FRV Soela, S 01/84/29, 2 February 1984; CSIRO CA4367, 261 mm total length pre-adult male, from southeast of Mermaid Reef, 17°18'S, 120°09'E, 304 m, FRV Soela, S 0184/39, 4 February 1984; NMV A9656, 254 mm total length pre-adult or adult male, from 85 km southwest of Geraldton, 29°15'S, 113°56'E, 320-325 m; NTM S12641-021, 297 mm total length adult male, from northwest of Lynher Bank, 14°50'S, 121°35'E, 275-280 m, J. Baillie, 15 December 1989; NTM S14266-006, 202 mm total length pre-adult female, from northwest of Houtman Abrolhos, 28°15.9'S, 113°19.5'E, 240-333 m, P. Alderslade, 11 July 1987; WAM P 26270-010 (2), 214 mm TL, 244 mm TL, 230 km NW of Beagle Island, WA, 15°30'S, 120°58'E, 280-320 m, FRV Courageous (P. Brown), shot 0751, 28 June 1978; WAM P 28105-003 (2), 179 mm TL, 184 mm TL, 100 km SW of Rowley Shoals, WA, 18°10'S, 118°16'E, 276-278 m, N. Sinclair and P. Berry, 24 August 1983; WAM P 30581-004 (2), 238 mm TL, 244 mm TL, 17°17°00'S, 120°11°00'E, 304-305 m, FRV Soela, 4 February 1984.

Northern Territory - NTM S13065-002 (4), 275 mm total length adult male, 216-262 mm total length pre-adult to adult females, from north of Bathurst Island, 09°49'S, 130°15'E, 260 m, FRV Invincible, D. Evans, 12 December 1990; NTM S13147-013 (4), 272-285 mm total length pre-adult to adult males, 312-321 mm total length adult females, 09°37'S, 130°26'E, 255 m, FRV Invincible, D. Evans, 9 December 1990; NTM S13578-009, 311 mm total length adult female, 08°55.3'S, 133°41.1'E, 179-187 m, RW 92-66, R. Williams, 20 October 1992; NTM...
S13579-004, 240 mm total length pre-adult female, 09°01'S, 133°19'3'W, 193-195 m, RW 92-68, R. Williams, 20 October 1992; NTM S13580-039 (4), 241-267 mm total length pre-adult males, 325-328 mm total length adult females, 09°04'7'5'E, 179-205 m, RW 92-68, R. Williams, 20 October 1992.

Indonesia – MNHN 1996-1557 (4), 144 to 162 mm total length pre-adult females, 145 mm total length pre-adult male, from off Tanimbar Island, 9°26'S, 131°13'E, 225 m, R/V Karabar, sta. CP86, 4 November 1991.

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The larval morphology and host of the Australian water mite
*Limnochares australica* (Acari: Hydrachnidia: Limnocharidae)

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Abstract - The present study deals with the larval morphology and host-parasite association of *Limnochares (Cyclothrix) australica*, a water mite from standing waters throughout Australia. The larva can be separated from the other described *Limnochares* spp. larvae, including the other *Cyclothrix* species of the area *L. (L.) crinita* by its unusual leg claws.

The larvae of *Limnochares australica* were found as parasites of the water strider *Tenagogerris pallidus* (Gerridae, Hemiptera, Insecta). *Limnochares australica* is the only known *Cyclothrix* species parasitizing Gerridae.

INTRODUCTION

The water mite *Limnochares (Cyclothrix) australica* Lundblad, 1941a inhabits standing waters in widespread regions of Australia. So far, the species is known from Tasmania, Victoria, New South Wales and Western Australia (Harvey, 1990, 1998). The second author collected the species also in the Northern Territory and in the Kimberley (northern Western Australia). Hence, it is likely that the species occurs throughout Australia. Outside Australia, the species has been reported from New Zealand (Smit, 1996).

Adults of *Limnochares australica* and *L. (Cyclothrix) crinita* Koenike, 1898 from India and Africa are impossible to separate. Cook (1967) based his separation on the disjunct distribution of the genus. The adult specimens from New Zealand were also similar to those from Australia (Smit, 1996), and were therefore assigned to *L. australica*. Harvey (1990) suggested that the larvae might provide useful characters to distinguish the two species. As the larva of *L. crinita* has been described (Wiles, 1993), the first aim of this paper is to give a detailed description of the larva of *L. australica* and draw conclusions on the conspecificity of the two species. When a larval description is available from New Zealand specimens, a similar conclusion can be drawn on the taxonomic status of the New Zealand populations.

Larvae of water mites are usually parasitic on freshwater organisms, mostly insects. So far, very few host relationships have been reported from Australia, and almost nothing is known about the life cycle of Australian water mites. One record of a water mite larva came from Canestrini (1884), who reported *Hydrachna odontognatha* Canestrini, 1884 parasitic on a water beetle. Unfortunately, his description of the larva is inadequate, and the species is considered a species incerta. The only Australian species of which more is known on the life cycle is *Physolimnesia australis* Halik, 1940. Proctor (1997) reported that the larvae forgo the parasitic stage. Hitherto, there is only one well-supported host-parasite association for Australian water mites. Womersley (1954) reported a mite, *Mackerraseliella globus* (later transferred to *Hydryphantes globus* Womersley, 1954 by Vercammen-Grandjean, 1972), as parasite of a dolichopodid fly. Thus, the second aim of this paper is to report an additional host for an Australian water mite species.

METHODS AND MATERIALS

Larvae of *Limnochares australica* were taken from the water strider *Tenagogerris pallidus* Andersen and Weir, 1997 (Hemiptera, Gerridae). These water striders were collected by the second author from a pool near the Manning Gorge Falls, The Kimberley, Western Australia on 13 September 1998. For the identification of the larvae the keys of Prasad and Cook (1972) and Smith and Cook (1991) were used. Moreover, adults of *L. australica* were abundant in this pool and it is assumed that the larvae belong to this species.

Two males and one female water strider were collected and preserved in Koenike's fluid. Six water mite larvae were attached to these three water striders: antennal segment 2 (larva 1, gerrid 2), dorsal side of thorax (larva 2, gerrid 1), abdominal segment VII (larva 3, gerrid 3), frons of
head (larvae 4 and 5, gerrids 2 and 3) and femur of first leg (larva 6, gerrid 2).

The larvae were in bad condition (lack of setae, legs and gnathosoma, damaged idiosoma). A preliminary description is given nevertheless, because the most remarkable characters are visible. The larva is described according to the nomenclature of Prasad and Cook (1974) and Smith and Cook (1991). All measurements are given in µm. If more than one specimen was measured, range and mean are given in parentheses.

Abbreviations are used as follows: CXI-CXIII: coxal plate I-III; Mp1-Mp2: mediopropodosomal setae 1-2; Lp1-Lp2: lateropropodosomal setae 1-2; C1-C4: coxal setae 1-4; Mmcp: medial margin of coxal plate; Pmcp: posterior margin of coxal plate; V1-V4: ventral setae 1-4; PI-PV: palpal segment I-V; IL1-IL6: 1st segment of the 1st leg - 6th segment of the 1st leg; IIL1-IIL6: 1st segment of the 2nd leg - 6th segment of the 2nd leg; IIII1-IILL6: 1st segment of the 3rd leg - 6th segment of the 3rd leg; Expp: excretory pore plate.

Description of the larva of *Limnochares australica*
The only larva with an intact idiosoma is specimen 1 which is obviously only slightly engorged (see Figure 1A). Length of its ovate idiosoma is 581, width 456. In the other 5 larvae, the idiosoma is very swollen. Many setae are lacking on the gnathosoma, idiosoma and legs; often, leg setae are represented only by the setal bases.

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**Figure 1** Larva of *Limnochares australica*. A. specimen 1 ventral; B. urstigma located between coxal plates CXI and CXII; C. excretory pore plate (specimen 4). Scale bars: A 100 µm, B, C 20 µm.
Dorsal idiosoma (see Figure 2): Integument noticeably porose, only lined around the small, distinctly lined dorsal plate which bears 4 pairs of setae; idiosoma posterior to dorsal plate with 6 pairs of visible setae. Dorsal plate length (n=2) 105-118 (111), width (n=3) 133-143 (137). Eye capsule length (n=2) 25-28 (26), Mp1-Mp1 (n=1) 89, Mp2-Mp2 58, Lp1-Lp1 109, Lp2-Lp2 116, Mp1-Lp1 14, Mp2-Lp2 56, Mp1-Mp2 37, Lp1-Lp2 28.

Ventral idiosoma (Figure 1A): Integument lined; sclerotization of the separate coxal plates porose. CXI bearing two setae, CXII and CXIII bearing one seta each. Each urstigma in two parts (Figure 1B). Only three pairs of setal bases of ventral setae visible. Length CXI (n=2) 35-39 (37), width 73-74 (74), length CXII (n=3) 45-49 (47), width 71-79 (74), length CXIII 40-43 (42), width 71-75 (72), C1-C2 (n=2) 16-19 (18), C1-Mmcp 18-18 (18), C4-Pmcp 16-18 (17), C1-C4 95-107 (101), C1 (n=1) 31, C2 23, C3 22, C4 25, V1 (n=2) 32-36 (34), V2 (n=1) 54. Excretory pore plate drop-shaped, bearing only one pair of setae (Figure 1C). Excretory pore oblong, lying between excretory pore plate setae; length of these setae (n=3) 60-88 (77), distance between them 56-72 (63). Length of Expp (n=3) 80-100 (96), width 80-92 (87).

Gnathosoma: Distinctly set off from the idiosoma (see Figure 1A). Length of PII (n=1) 32, length of PIJI 21, length of palpal claw 20.

Legs of more-or-less equal length (Figure 3A-C). Two types of tarsal claws (Figure 3D), one simple and falciform, the other with lamella-like widening at its base. Chaetotaxy of the legs not clear, often not even setal bases visible. All leg segments lined and this is particularly distinct on distal segments (Figure 3D).

Leg I (Figure 3A): total length (n=3) 198-208 (203); length IL1 25-28 (27), IL2 21-23 (22), IL3 22-23 (22), IL4 37-38 (37), IL5 37-38 (37), IL6 64-66 (65); height IL1 23-25 (24), IL2 25-26 (25), IL3 26-28 (27), IL4 22-23 (22), IL5 23-24 (24), IL6 18-19 (19).

Leg II (Figure 3B): total length (n=4) 191-208 (199); length IIL1 27-29 (28), IIL2 22-27 (25), IIL3 21-23 (22), IIL4 27-29 (28), IIL5 34-37 (36), IIL6 60-63 (61); height IIL1 23-25 (24), IIL2 22-23 (23), IIL3 24-25 (25), IIL4 22-23 (22), IIL5 23-24 (24), IIL6 17-18 (18).

Leg III (Figure 3C): total length 189-205 (197); length IIIIL1 24-27 (26), IIIIL2 24-25 (25), IIIIL3 21-23 (22), IIIIL4 27-29 (28), IIIIL5 36-39 (37), IIIIL6 57-62 (59); height IIIIL1 22-24 (23), IIIIL2 21-22 (21), IIIIL3 21-23 (22), IIIIL4 18-21 (20), IIIIL5 20-21 (20), IIIIL6 16-20 (18).
DISCUSSION

The family Limnocharidae is divided into the two subfamilies Limnocharinae and Rhyncholimnocharinae (see Cook, 1974). The only known larva in the latter subfamily, *Rhyncholimnochares* *kittatiniana* Habeeb, 1954, was described by B.P. Smith (1989). There are marked differences in morphology and parasitism between this *Rhyncholimnochares* larva and the known larvae of *Limnochares*. The larva of *Rhyncholimnochares* *kittatiniana* is characterized by a dorsal plate bearing 7 pairs of setae and an excretory pore plate devoid of setae. In contrast to the larvae of *Limnochares*, larvae of *R. kittatiniana* parasitize elmid beetles.

In the subfamily Limnocharinae, five species of the genus *Limnochares* are known worldwide. There are two subgenera described, *Limnochares* with one holarctic species, and *Cyclothrix*, with species known from Africa, Asia, Australia and North America. Larval descriptions of *L. (Limnochares)* *aquatica* (Linnaeus, 1758) are given by Lundblad (1927) and Wainstein (1980), of *L. (Cyclothrix)* *americana* Lundblad, 1941b by Crowell (1963) and Prasad and Cook (1972) and *L. (Cyclothrix)* *crinita* by Wiles (1993). The following discussion on morphological data is based on these descriptions.

The larva of *L. (Cyclothrix)* *australis* shows some characters which separates the species from the other known Limnocharinae. The most distinct character is found in the claws. All larvae of the Limnocharidae bear only two claws, a specific characteristic of the family. In larval *L. americana*, *L. crinita* and *L. aquatica* both claws are equal, heavy, long and falciform. In *L. australis*, only one claw belongs to this common *Limnochares* type, the other

Figure 3  Larva of *Limnochares australis*. Legs (different specimens). A. IL lateral. B. III. lateral. C. III. lateral. D. Leg segment 6 and claws of leg I, setae not drawn. Scale bars: A–C 100 μm, D 20 μm.
The water strider parasite *L. australica*, *L. crinita* parasitizes Odonata (Wiles, 1993). The separation of the *Limnochares* subgenera by their host taxa is not possible by the so far reported hosts.

The autecology of *Limnochares aquatica* was studied in great detail by Böttger (1972), and parts of the life cycle of *L. americana* were described by Crowell (1963). As in the present study for *Limnochares australica*, Böttger (1972) reported different attachment sites on gerrid hosts for *L. aquatica*; parasites were found on all three tagmata of the hosts.

Based on the description of the larva of *L. australica* presented here, the *Limnochares* species from New Zealand (see Smit, 1996) may possibly be classified systematically from its larval morphology and host-parasite association.

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**REFERENCES**


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Abstract — The first attempts at scientific dating of petroglyphs in the Pilbara region of Western Australia are reported. Using microerosion analysis, a calibration curve has been established on the basis of a series of engraved historical dates, which is then used to estimate the ages of several petroglyphs. The results indicate that some of these are of Pleistocene antiquity. The consistency of the preliminary results of this project with observations made elsewhere in Australia and abroad is noted.

THE DATING OF PETROGLYPHS

Rock art occurs in two forms: as the results of additive processes, in the form of pictograms (paintings, stencils, drawings, beeswax figures); and as petroglyphs, i.e. the results of reductive processes (pounding, abrading, engraving, pecking, drilling). This division immediately determines the fundamentally different approaches to rock art dating, or rather, to estimating its antiquity. The substances added to the rock surface in the creation of pictograms provide the analyst with a variety of datable compounds that are of ages closely resembling the time the art was produced. For instance, paint residues may contain remains of organic binders or diluents (blood, saliva, orchid juice etc.) or pigments (charcoal, cochineal, berry juice etc.), as well as a great variety of incidental inclusions (brush fibres, pollen, bark fragments etc.) that contain radiocarbon of adequate quantities to permit accelerator mass spectrometry (Cole and Watchman 1992; but cf. Ridges et al. 2000). The fine-grained mineral detritus removed in the production of petroglyphs is, however, not likely ever to be recovered for analysis (cf. recent attempts by G. Susino to do so). Therefore, in order to date petroglyphs directly we have to resort to analysing a physically related feature that either pre- or post-dates the art (lichen, accretionary skin or crust, biogenic deposit etc.), providing a minimum or maximum age. In the language of Dunnell and Redhead (1988), such a procedure fails to focus on the ‘target event’, which is the creation of the petroglyph. Moreover, most of the methods used are seriously impaired by inherent uncertainties. For instance, dating bulk carbon isotope concentrations in accretionary crusts may be severely misleading, particularly if the crusts are open systems (Bednarik 1979, 1994a; Nelson 1993; Dorn 1997). Thus, the dating of petroglyphs remains one of the most intractable problems in archaeology. Indeed, of the methods proposed for petroglyph dating, only microerosion analysis (Bednarik 1992) seeks to determine Dunnell and Redhead’s (1988) ‘target event’. This paper presents the first application of this technique in Australia, and the first scientific age estimates for Pilbara rock art.

Until the early 1980s, no inherently testable methodology had become available for the age estimation of rock art (Ward and Tuniz 2000). Previous dating claims had generally been based on non-scientific criteria, and in the case of petroglyphs it had been sought to determine the ages from their perceived iconographic content (i.e. what the art was thought to depict), style or technique; from spatial proximity to archaeological evidence (such as occupation debris) and by excavation (usually of purported occupation deposits); or from superimposition, patination and weathering.

Iconographic interpretation, however, is not falsifiable in most instances, and stylistic constructs, while possibly comprising some valid elements, are not a sound basis for dating rock art, as has been demonstrated time and again in various continents (e.g. Macintosh 1977; Bahn and Lorblanchet 1993; Bednarik 1995a, b; Watchman 1995, 1996). Not only are such mental constructs of researchers untestable, they tend to reflect modern Western perception more than historically valid variables inherent in the rock art. They are also taphonomically naive in that they ignore that the surviving vestiges of any rock art are not random samples of living traditions (Bednarik 1994b), and they tend to be formed without adequate recourse to archaeometry. The technique of petroglyph execution, too, is rarely a reliable chronological marker, and should not be cited as a dating criterion without substantial other evidence. Proximity to occupation sites is almost irrelevant in the reliable dating of rock art, because rock art often occurs at ‘focal’ sites within a landscape, as do occupation debris, hence their co-occurrence is more likely to be related to this factor than to contemporaneity.
Superimposition of motifs certainly provides sound data for relative sequences, but is not always reliably determined without the use of field microscopy and does not yield actual age estimates, so in rock art dating it is only useful as a supplementary method.

There are two basic approaches to dating rock art by excavation. The petroglyphs, either on a vertical wall or on horizontal bedrock, may have been covered by subsequent sediment deposition (Rosenfeld et al. 1981; Steinbring et al. 1987; Crivelli et al. 1996), or detached and stratified fragments of rock bearing petroglyphs may be excavated in an occupation deposit (Hale and Tindale 1930; Mulvaney 1969: 176; Thackeray et al. 1981; Lorblanchet 1992; Fullagar et al. 1996). In all these cases the dating of the sediment can only provide minimum ages for the petroglyphs, and it is dependent upon the validity of a chain of unfalsifiable deductive arguments relating to the taphonomy of both the excavated sediments and the dated material (e.g. charcoal). Moreover, and especially in the case of rock art on vertical walls or detached fragments, the minimum age secured from the sediment is likely to be very conservative. Also, archaeological claims about the dating of sediments need to be viewed sceptically, as there are numerous cases on record of incorrectly dated sediments related to petroglyphs. For instance at Fariseu, Portugal, a colluvium of probably less than 17 years of age was claimed to be around 25,000 years old (cf. Abreu and Bednarik 2000), and at Jinmium, in the Keep River region of northern Australia, a saprolithic sediment of the Holocene was claimed to be over 170,000 years old (cf. Roberts et al. 1998).

Indeed, of the traditional methods of estimating the ages of petroglyphs, only the study of subsequent patination and weathering promises secure or testable data, and although it was perhaps the first to be considered (Belzoni 1820: 360–61), it has not been applied in a rigorous and systematic fashion up to the present time (but see Trendall 1964). Instead of pursuing the development of a scientific methodology to date petroglyphs, archaeology has for the greater part of two centuries opted for an 'archaeological methodology', which consists of non-quantifiable speculations, unexplained perception of invented styles and non-falsifiable propositions. The use of these untestable and thus non-scientific approaches continues to the present time, and is sometimes defended vigorously by archaeologists (Zilhão 1995; Rosenfeld and Smith 1997).

The alternative approach is by 'direct dating', the use of direct physical relationship of art and dating criterion, and the presentation of falsifiable propositions concerning this relationship for the purpose of estimating rock art age (Bednarik 1996; for a comprehensive critique of all rock art dating methods, including those contributed by me, see Bednarik 2001: 111–137).

MICROEROSION ANALYSIS

Microerosion analysis seeks to estimate the actual age of petroglyphs. The rationale of this technique is that, after a new rock surface has been created, be it by natural or anthropic agents, it is subjected to chemical weathering processes. This applies especially in unsheltered locations, and it results in cumulative effects that are a function of time, among other factors. While this is a fairly self-evident principle, the difficulty in using the results of such processes to estimate the age of a rock surface is that our understanding of them, of their effectiveness on different component minerals, and of their susceptibility to environmental factors remains limited (concerning typical rates of solution, cf. Acker and Bricker 1992; Busenberg and Clemency 1976; Lin and Clemency 1981; Oxburgh et al. 1994; Rimstidt and Barnes 1980; Williamson and Rimstidt 1994).

For the time-span we are concerned with in dating petroglyphs (the last 50,000 years), only comparatively erosion-resistant rock types are

![Figure 1 Diagram depicting the laws of wane formation in a simplified form.](image-url)
suitable for microerosion analysis, because those that dissolve too fast are unable to preserve original fracture surfaces for time-spans long enough to be of relevance. Sedimentary rocks, in particular, weather so fast that remnants of the surfaces created at the time a petroglyph was made survive only for very short periods. So far, two different methods have been used. In one, the retreat of the more soluble component of a rock is measured against a component that retreats at an extremely slow rate. For instance the retreat of amorphous silica cement in a heavily metamorphosed quartzite can be measured against the crystalline quartz component, or the alveolar retreat seen in schistose rocks can facilitate rough age estimates. However, the principal technique used so far is the measurement of micro-wanes on fractured crystals (Bednarik 1992, 1993a). The ‘radius’ of wanes (strictly speaking, wanes are not equi-circular in section, but hyperbolic) increases as a linear function of age, as demonstrated by the geometry of the process. In wane formation, be it at the macroscopic or microscopic level (Figure 1), the ratio $h:r$ is constant for any angle $\alpha$, irrespective of distance of retreat of the faces and the edge. Ratio $x : z$ is a function of $\alpha$, and for instance at $\alpha = 60^\circ$, $x = 2z$. Dimension $x$ can be expressed in algebraic fashion:

$$x = \sqrt{\left(\frac{z}{\tan 0.5\alpha}\right)^2 + z^2}$$  \hspace{1cm} (1)

This leads to the prediction of $\beta$, the angle expressing the rate of wane development relative to surface retreat:

$$\beta = \sin^{-1}\left(\frac{r}{x + h + r}\right)$$  \hspace{1cm} (2)

The relationship wane width $A$ versus age, irrespective of actual retreat, is ultimately determined by the ratio $\alpha : \beta$, which must be established empirically. It follows that the dimensions $A$, $r$, $z$, and angles $\alpha$ and $\beta$ in Figure 1 are all related geometrically and algebraically, and that the variables $A$, $r$, $x$, $z$ and $h$ are all proportionally equivalent, and increase linearly with age. Of these, $A$ is most easily measured physically in the field. It is therefore the variable preferably used in micro-wane measurement.

In the field, the analyst scans the rock surface microscopically to locate crystals that have been truncated (either fractured by impact or truncated by abrasion) by the event to be dated (e.g. the petroglyph production). A statistically significant sample of micro-wane widths along the edges of such truncation surfaces is recorded and placed in a calibration curve. Age estimates are prefixed with a capital $E$, indicating that the result is erosion derived.

The method is not very precise at this early stage, because it has only a few calibration points in each region where it has been applied. The principal variables in the solution process responsible for microerosion are temperature, $pH$ and moisture availability. The first two are regarded as unimportant. Variations in mean annual temperatures, even as far back as glacial peaks of the Pleistocene, are not thought to have been of a magnitude that would have affected solution rates appreciably. Variations in $pH$ back through time can be assumed to have taken place, but they are just as unlikely to have influenced solution rates. In the case of both amorphous silica and crystalline quartz, there is almost no change in solubility below $pH$ 9, and higher values would certainly not have been experienced in nearly every natural environment. For alumina the effect is negligible in the central region of the $pH$ scale, which coincides with most natural conditions. Precipitation certainly varied in the past, but it can be accounted for. Significant changes in moisture availability affect component minerals differently, and should thus be detectable by calibration of more than one component mineral. Therefore it is preferable to apply the method to two or more different component minerals of the same surface, such as quartz and feldspar.

While microerosion analysis is not thought to be very accurate, it is probably more reliable than most alternative methods of dating petroglyphs, and it is certainly cheaper, simpler and more robust than most. It requires no laboratory facilities. Results can be determined in the field, which may save considerable effort necessitated by the need to return to a perhaps very remote site to obtain supplementary data. The method provides not a single result, but clusters of age-related values (the micro-wane widths) that can be converted into various statistical expressions – a luxury not available to all other dating methods currently used. Moreover, it is the only such method offering a means of internal checking – that is, of checking the validity of the result without recourse to another method (although luminescence dating has a limited feature of this type, i.e. the possibility of checking whether the uranium and thorium decay chains are in equilibrium). Finally, microerosion analysis involves no removal of samples, or even contact with the rock art, being a purely optical method.

All these factors favour microerosion analysis. The valid technical arguments against the method are: inadequate calibration curves, its limited
accuracy through its inherent coarseness, its application is limited to rock types that preserve crystal surface features and have been continuously exposed to precipitation. These significant limitations are outweighed by the benefits of the method. The microerosion method by micro-wane measurement has been used on petroglyphs in six blind tests: in Russia, Italy and Bolivia (Bednarik 1992, 1993a, 1995b, 1997a, 2000a). Archaeological expectations were matched in all but one case, where the results matched those of other scientific analyses (Bednarik 1995b; Watchman 1995, 1996). Calibration curves are now available from Lake Onega (Russia), Vila Real (Portugal), Grosio (Italy), Qinghai (China; Tang 2000), Jubbah (Saudi Arabia) and eastern Pilbara (Australia). The technique has also been applied in India and South Africa. The method’s practical time range on crystalline quartz, from perhaps 50,000 years BP to the present, renders it particularly suitable for rock art, very little of which can be expected to be in excess of that range. The perhaps most effective range (from around 10,000 years to about 1000 years) coincides with the presumed age range of most petroglyphs.

PILBARA PETROGLYPHS

The rock art of the Pilbara region in north-western Australia (Figure 2) is reputed to be the world's largest concentration of petroglyphs. This remained unrecognised until the 1960s when the majority of the sites were located and first examined. Systematic scientific study of this massive corpus began with an expedition of the Western Australian Museum to Depuch Island in 1962 (Ride and Neumann 1964), followed by the survey work of Bruce Wright in the region from Roeburne to the Upper Yule River (Wright 1968, 1972). My own work, involving the finding and study of hundreds of sites, began in 1967 (Bednarik 1973) and is still continuing into the 21st century.

However, the work conducted during the 1960s was not without precedents. The first recorded reports of any Pilbara rock art are those of Wickham (1843) and Stokes (1846: 166-77), recording the visit of Depuch Island by H.M.S. Beagle in 1840. The crew of that ship left at least three inscriptions behind. Captain Wickham took a particular interest in the petroglyphs and his illustrations were republished by Stokes. These authors, however, were probably not the first Europeans to view the rock art. Much earlier, in 1688, buccaneer William Dampier, after whom the Dampier Archipelago is named, visited the north-western coast and may well have seen rock art, but in his very brief account about Australia (under 2500 words) he makes no mention of it. A recent discovery in the eastern Pilbara, however, suggests that a European of the 18th century, presumably living with indigenes, not only saw the rock art but added his own designs (see below).

Figure 2  Map showing the principal rock art sites of the Pilbara region, Western Australia.
Much later, Pilbara petroglyphs are briefly mentioned by Richardson (1886), while Withnell (1901) dedicates a page to them. In 1939 the Frobenius Institute of Germany conducted brief expeditions to three localities - Abydos, Port Hedland and Depuch Island - which resulted in some preliminary descriptions (Fox 1939; Petri 1954; Petri and Schulz 1951). Davidson's visit in 1938–39 is reflected in his opinions about similarities with other Australian rock art (Davidson 1952), but the first study of substance was the work of another German researcher, Father E. A. Worms, who conducted field work in 1931 and in the early 1950s (Worms 1954). His observations, especially in the Abydos area, led him to suggest that many anthropomorphic petroglyphs there with certain distinctive features were connected with the Kurangara cult, introduced from the east and originating in Arnhem Land. This deduction is no longer accepted today (McNickle 1985) and the figures in question are now called 'Woodstock figures'.

More detailed reports only began to appear in the 1960s, first of the 1958 study by F. D. McCarthy on Depuch Island (1961), then his subsequent comprehensive survey of the limestone ridge at Port Hedland (1962), where he determined the presence of about 7000 motifs, spread over a distance of more than ten kilometres. Most of these figures were still well preserved when I first saw the site complex six years later, but by the end of the century only a few hundred motifs remained. The massive industrial development at Port Hedland had resulted in the gradual deterioration of that rock art corpus. The destruction of rock art was of an even greater scale on Burrup Peninsula, where I witnessed the loss of many thousands of motifs during the 1960s. The 1962 expedition to Depuch Island by the Western Australian Museum (Ride and Neumann 1964) was in fact prompted by a proposal to construct a deepwater port for loading iron ore on the island. The recommendations of the Museum team effectively led to the abandonment of this plan, and to developing instead the loading facilities at Dampier in 1960s. Wright's painstaking site recording program (Bednarik 1973) and still continuing (Bednarik 2000b), differs from previous research efforts up to the mid-1960s, of that rock art corpus. The destruction of rock art was of an even greater scale on Burrup Peninsula, where I witnessed the loss of many thousands of motifs during the 1960s. The 1962 expedition to Depuch Island by the Western Australian Museum (Ride and Neumann 1964) was in fact prompted by a proposal to construct a deepwater port for loading iron ore on the island. The recommendations of the Museum team effectively led to the abandonment of this plan, and to developing instead the loading facilities at Dampier in the mid-1960s, where no survey work had taken place prior to 1968. Abydos was also visited by Mountford (1968).

The principal limitations of all research efforts up to the mid-1960s were that they usually dealt with individual sites or site complexes and were the result, generally, of rather brief visits; they lacked in-depth consultation of Aboriginal informants, which has severely limited the amount of authentic ethnographic information available about Pilbara rock art; and until Trendall's (1964) work there was no attempt to provide analytical data. Because of this piecemeal approach it was only with the work of Wright (1968, 1972) and myself during the 1960s that the true magnitude of the Pilbara petroglyph corpus began to become apparent. Wright was the first to conduct broadly based inter-site studies over a wide section of the region, and thus to define this distinctive rock art province. Indeed, his quantitatively descriptive study, extending over two years and then intermittently into the early 1970s, has not been bettered to the present time, even though much better funded projects have been undertaken during the subsequent three decades. Wright kept interpretation of the rock art to a minimum and endeavoured to provide comprehensive initial descriptions, particularly of the significant and spectacular anthropomorphic component of the region's rich iconography. Because his recordings were derived from a meticulous photographic record, on which the early component of the art tends to be invisible due to repatination, he only registered the more recent technological traditions in most instances, as had also been the case with all previous research endeavours. Importantly, Wright was the first to conduct in-depth ethnographic research, particularly through the cultivation of personal rapport with indigenous elders in Roebourne.

My own study of Pilbara petroglyphs, commenced in 1967 (Bednarik 1973) and still continuing (Bednarik 2000b), differs from previous work in the region in various aspects. It is a long-term project that initiated archaeological studies in the region (Bednarik 1977), but focused on extracting scientific and ethnographic information (Bednarik 1979, 1998). I soon noticed the occurrence of entirely re-patinated, almost invisible petroglyphs of great antiquity, which had been overlooked by previous investigators. If they occurred by themselves, they were very difficult to find, and if they occurred with much more visible recent figures they had remained undetected. They led me to differentiate artistic traditions of greatly varying, but unknown, age. Motivated by wanting to place the rock art into an archaeological context rendered it essential for me to focus particularly on the question of the art's antiquity, because it can only become an archaeologically meaningful resource if its age is known - at least approximately.

Wright's painstaking site recording program involved close to 100 sites, and my addition of several hundred more sites in the western Pilbara (about 570 sites just on the Burrup Peninsula) demonstrated that the Pilbara contains the largest known assemblage of petroglyphs. Some of the more enthusiastic estimates, such as the suggestion that there are 500 000 petroglyphs just on Burrup (Lorblanchet 1986), are perhaps excessive. However, the number of petroglyphs now known in the Pilbara is at least in the hundreds of thousands, with perhaps in the order of 2000 sites known, many of which number in excess of 1000 motifs.
Once the magnitude of this corpus became apparent it attracted the interest of other researchers, and in particular the Dampier sites became the subject of several studies (Virili 1977; Lorblanchet 1983, 1992; Vinnicombe 1987). These and other research projects were usually connected with industrial developments and were therefore often well funded, but they were also highly biased in favour of specific localities and corporate or governmental preoccupations. Elsewhere in the Pilbara, little further rock art research took place, although there are some exceptions (e.g. Palmer 1975; Maynard 1980; McNickle 1985; Brown 1987). Since Wright's first tentative but inconclusive forays into the question of petroglyph antiquity, no hard evidence has become available. Concerning Burrup rock art, Clarke (1978) stated his opinion that some of it must be in excess of 17 000 years old, based on his assumption that the patina found on it, which he thought to be desert varnish, formed during a very arid phase at about that time. However, much of the patina is not of the varnish type, nor does that kind of accretionary deposit indicate arid conditions.

An attempt was made by Lorblanchet (1992) to archaeologically date the petroglyphs at Gum Tree Valley and Skew Valley on the western Burrup Peninsula. He obtained a series of radiocarbon dates ranging in age from 7000 to c. 500 BP. Only the three youngest dates were secured from charcoal, all others are from marine shells. A date of about 18 500 BP came from fragments of a trumpet shell (Syrinx aruanus) found on the present land surface, some distance from the petroglyphs. On the basis of this rather slender evidence, Lorblanchet constructed a chronology of successive petroglyph traditions extending back over 18 000 years (Lorblanchet 1992: Figures 20, 21), which is unlikely to be valid since it relies on a single shell date. Moreover, the Burrup would then have been over 100 km from the sea shore and rather inhospitable - the consequence of full glacial aridity.

In the Pilbara, the most likely place to find Pleistocene occupation debris is inland, along river courses, at waterholes, soaks, springs and in rockshelters, especially in areas of relatively impermeable rock, particularly granites, which allow aquifers to remain close to the surface throughout the year. Much of the eastern Pilbara fits this description. Despite its arid ecology, there are reliable supplies of permanent water close to the surface, and aquifers are sometimes exposed even in quite flat areas. Morphologically, the piedmont region is dominated by roughly conical boulder piles which in some areas occur in large groups and are generally of granite facies (Figure 3). Sub-parallel dolerite dykes occur locally and can be hundreds of kilometres long. Drainage of the occasionally cyclonic and always unpredictable rainfall is effected via substantial river systems, most of which carry little or no water for much of the year. Rock art is found at hundreds of the many boulder piles, and even the most cursory examination reveals the presence of many traditions separated by great time spans. The earlier components of these rich sequences of petroglyphs could well be of Pleistocene age.

Figure 3 Typical granite boulder pile of the eastern Pilbara. This is Spear Hill site 7, the principal calibration site in this project.
ESTABLISHING A CALIBRATION CURVE

Twenty-two years after commencing my research in the Pilbara, my development of the microerosion method in 1989 seemed to render Pilbara petroglyphs datable at last. Unfortunately, in Australia, and most especially in the remote and very thinly populated north-west of the continent, there are no rock surfaces of historically known ages available to establish calibration curves. The great wealth of rock-made structures, quarries, gravestones and glacial abrasions in Eurasia whose age is either known precisely or can be ascertained with reasonable accuracy renders this region far more amenable to this method. In July 2000 I managed to locate a large series of engraved dates on one of the four major granite facies of the eastern Pilbara, which provided the means of securing calibration values for this important rock art region (Figure 4).

While surfaces of historical structures (Roman bridges, Buddhist inscriptions) and glacial striae from the end of the last stadial have been utilised in Eurasia, dated inscriptions of the last two centuries seem to be the only available option in Australia. I had already used dated inscriptions very profitably abroad, but in the case of Australia, the exceedingly short time range covered by such dates would introduce a higher level of imprecision. However, the potential imprecision imposed by an arid climate could be considerably greater than that of very short-range calibration values.

The series of dated inscriptions located in the Pilbara includes an apparently authentic example from 1771, which is part of the earliest currently published non-indigenous rock art composition yet found in Australia (Bednarik 20(X)b; I emphasise that I know of two earlier European inscriptions). It consists of four motifs, two of which show limited evidence of the application of a metal implement prior to completion with a pounding stone (Figure 5). The panel is still being subjected to further research, and this work may lead to the development of a calibration curve for olivine or pyroxene. It was engraved on a basaltic dolerite, free of quartz and feldspar, and therefore cannot be utilised for microerosion analysis until one of its constituent minerals has been subjected to a calibration study.

The remaining engraved dates recently discovered in the eastern Pilbara and examined for constructing a calibration curve are all located on
AGL granite, a well foliated, fine to medium-grained biotite adamellite representing remobilised older granitic rocks. Eight dates ranging from 1881 to 1997 were surveyed with a specially adapted field binocular microscope. Six lie near the peak of Spear Hill site 7, one on the hill's western flank and one on nearby Spear Hill site 9 (McNickle 1985). Six of these inscriptions provided quantifiable micro-wane width readings from 90° fracture edges on crystalline quartz (see Bednarik 1992, 1993a), with samples ranging from four to thirty-two measurements per inscribed date (Table 1).

The calibration curve derived from these values (Figure 6) provides a reasonably distinctive trend, although the values recorded for the 1964 date are not a good fit. However, only four determinations were possible which is statistically inadequate.

remaining values fit well, but the resulting curve differs considerably from those secured previously from temperate to sub-Arctic sites. This was certainly expected, and the difference is not even as great as one might have predicted, considering the much greater difference in precipitation (cf. Bednarik 1992, 1997a). However, erosion rates in an arid climate may well be determined not so much by annual precipitation, but by the relative duration of surface moisture, which is determined by the length of rainfall periods and evaporation rates. In that sense, the Pilbara with its cyclonic precipitation, very low relative air humidity and sparse vegetation is probably close to the end of the spectrum of mineral solution rates in common natural environments. The ubiquitous iron-rich accretions of the entire region, which have previously been interpreted as autochthonous conversion products, are another result of these conditions, being largely, though certainly not entirely, the outcome of inadequate flushing of dissolved minerals.

Two other points need to be emphasised. First, this calibration curve lacks in precision for a number of reasons, especially the short range of the calibration values it is based on. Second, its reliability could be backed up by a feldspar curve. This first determination for the Australian Pilbara is therefore best regarded as preliminary, subject to refinement and testing, and its purpose is merely to explore the time depth represented by Pilbara rock art and to set some of the parameters within which future datings of Pilbara petroglyphs are to be conducted.

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**Table 1** Microerosion calibration values (in microns) from micro-wanes on eight engraved dates at Spear Hill, Pilbara, for crystalline quartz.

<table>
<thead>
<tr>
<th>Date</th>
<th>No. of determinations</th>
<th>Min. width</th>
<th>Max. width</th>
<th>Mean width</th>
</tr>
</thead>
<tbody>
<tr>
<td>1938</td>
<td>15</td>
<td>0.1</td>
<td>0.4</td>
<td>0.233</td>
</tr>
<tr>
<td>1941-A</td>
<td>8</td>
<td>0.2</td>
<td>0.3</td>
<td>0.237</td>
</tr>
<tr>
<td>1980</td>
<td>Micro-wanes are slightly &lt;0.1 micron</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>Micro-wanes too small to measure effectively</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964</td>
<td>4</td>
<td>0.2</td>
<td>0.3</td>
<td>0.275</td>
</tr>
<tr>
<td>1941-B</td>
<td>32</td>
<td>0.2</td>
<td>0.4</td>
<td>0.259</td>
</tr>
<tr>
<td>1881</td>
<td>8</td>
<td>0.4</td>
<td>0.7</td>
<td>0.537</td>
</tr>
<tr>
<td>1917</td>
<td>8</td>
<td>0.3</td>
<td>0.7</td>
<td>0.412</td>
</tr>
</tbody>
</table>

**Figure 6** Microerosion calibration curve for quartz, Spear Hill rock art complex.
THE FIRST DATING OF PILBARA PETROGLYPHS

The Spear Hill calibration curve (Figure 6) has been applied to selected petroglyphs at three granite boulder piles: Woodstock 65B, Spear Hill 7 and Spear Hill 9 (Figure 2). In each case, fractured quartz crystals were located that had remained free of accretionary mineral deposits and possessed edge angles between 85° and 95°. The micro-wanes developed on these edges were then measured in accordance with standard microerosion analysis (Bednarik 1992, 1993a). Not every motif on granite is suitable for this kind of analysis, many are so extensively covered by accretionary mineral matter that weathering processes have been retarded. Such surfaces are unsuitable for microerosion analysis. However, the deposits are often sufficiently discontinuous, even on repatinated motifs that are of macroscopically even colour, that microerosion analysis is possible.

The ubiquitous reddish-brown patination of the entire Pilbara region is generally neither an intrinsic alteration product nor entirely an accretion, it is a combination of the two. On the dolerites, the magnetite component takes well under a century for an initial crust of iron oxides and hydroxides to form in situ, but on the granites there is only limited inherent potential for the development of alteration products. The accretionary matter is selectively deposited, sometimes its distribution is determined by aeolian factors, and its microscopic morphology is closely related to whether the support surface is vertical or horizontal. Distinctively ‘laced’ or ‘terraced’ morphologies are common. Under adequate magnification (>60x), the accretionary matter reveals a diversity of airborne materials, including widely transported mineral grains and charcoal detritus, and this is caked together mostly by iron salts and amorphous silica. These deposits were found to form fairly consistently as a function of time. An incipient film becomes evident after a surface has been exposed for 30–40 years, and after about 100 years, the patchy deposit reaches a thickness locally of 30–50 microns (μm). The thickness of the laced accretionary deposits in part of the above-mentioned 1771 inscription reaches 100–150 μm, which is crucial in assessing the authenticity of this composition. However, on granite such deposits remain often so discontinuous that fracture surfaces that have remained exposed can usually be found on all but the very oldest motifs.

Woodstock 65B

Woodstock site 65B is located near the abandoned Abydos homestead, on AGM granite, a fine to coarse, even-grained biotite adamellite, biotite granodiorite and, less commonly, biotite tonalite, well foliated and often gneissic. The hill is a typical conical boulder pile, rising about 80 m above the pediplain. It bears an estimated 2000 petroglyphs, which are scattered in several concentrations around its slopes, with a notable occurrence of very elaborate and detailed anthropomorphs found near the summit. Large boulders form a distinctive shoulder on the western slope, creating an area of level ground where petroglyphs of very different ages occur in close proximity, even on the same panels. They include circle motifs of a quite specific genre thought to be of the Pleistocene near the southern coast of Australia (Bednarik 1990). The upper surface of a small elongate boulder bears several deep impact scars (Munsell 10R-4.5/7) and an almost fully repatinated pounded circle, together with faint linear marks that may also be of former circles. Twenty quartz micro-wane widths (A) were measured in one of the impact scars (Table 2), yielding a mean value of 17.25 μm (range 10–30 μm). On the newly constructed calibration curve (Figure 6), this corresponds to an estimated age of E3670 (+2713–1543) years BP. The ‘E’ in front of the age estimate indicates that it is derived from microerosion analysis.

The immediately adjacent circle was also examined (Munsell 7.5R-4/6) and an area of suitable accretion-free quartz edges was located. Measurements of their micro-wanes yielded a mean width of 125.74 μm (range 110–180 μm, N = 14), which corresponds to E26 753 (+11 545–3349) BP. Thus, the lightly-patinated impact scars, which seem to be a more recent reaction to the earlier circle, are significantly younger than the circle.

Two metres to the south of this boulder, a well-rounded large boulder bears an only faintly patinated male anthropomorph. The quartz cleavage faces in this petroglyph appeared quite fresh under magnification. Analysis of their ≈90° edges produced a mean value of 2.0 μm (range 1–4 μm, N = 10). Consequently this typical Woodstock figure is only E425 (+426–212) years old (Table 2).

Some 10 m to the east of this motif is a large flat boulder, about 6 m long. Most of its horizontal upper surface has experienced massive laminar exfoliation of 3–5 cm thickness, but near its northern end, one square metre of patinated crust is still present. It bears the remains of a design of which four circles and an elongate, bisected outline in the Karake style (Aslin and Bednarik 1984) remain visible (Figure 7). This is heavily weathered (Munsell 10R-4/5, on 10R-3/5 background), and there is a patch of abraded area on the surviving panel. Fourteen micro-wane widths measured on the east side of the largest circle yielded a mean value of 91.07 μm (range 75–125 μm), suggesting that the design is E19 376 (+7219–3419) years old. The ground area, about 70 cm across (Munsell 5YR-8/4, but very speckled), is significantly younger. It is about the same age as the Woodstock figure just
R.G. Bednarik

Figure 7 Circle petroglyphs of the Karake style, estimated to be just under 20,000 years old.

mentioned: micro-wane sizes of about 2 μm are consistent, although no quantitative count was attempted.

Some of the most prominent petroglyphs at site 65B occur about 30 m north of the locality so far considered, on a highly visible dark boulder. The numerous motifs include female Woodstock figures. One of them, with distinctly S-shaped torso, exhibits wane widths of 10-15 μm, and is therefore between about E2130 and E3190 years old. The south-west wall of the large boulder bears at least 82 cupules, typically of 25-40 mm diameter and 5-10 mm deep. Unfortunately they are so heavily coated by accretorionary deposits that microerosion analysis could not be attempted. They appear to have continued onto the upper surface of the rock, and there could be taphonomic selection based on relative orientation evident. Several Karake-style crossed or bisected circles on the north-west side of the boulder appear to be of intermediate age. Although the cupules are not datable by the method used here, there can be little doubt that they are the earliest component of the rock art present. Their alveolar erosion patterns are well in excess of the condition observed in the c. 27,000-year-old motif. This observation of the precedence of cupules is consistent at many sites in the region, and elsewhere in Australia and the world (Bednarik 1994c).

Spear Hill complex
Two petroglyphs were examined at sites of the Spear Hill complex (for a detailed description of this extensive complex of about forty boulder piles, see McNickle 1985). The '1917' date included in the calibration curve, located at site No. 9, is just

<table>
<thead>
<tr>
<th>Motif</th>
<th>Wanes</th>
<th>Min. A</th>
<th>Max. A</th>
<th>Mean A</th>
<th>Age, years</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female SH7</td>
<td></td>
<td>No measurements taken</td>
<td></td>
<td>c. 350</td>
<td>E350</td>
<td>-</td>
</tr>
<tr>
<td>Male 65B</td>
<td>10</td>
<td>1</td>
<td>4</td>
<td>2.00</td>
<td>E425</td>
<td>+426, -212</td>
</tr>
<tr>
<td>Anthrop. SH9</td>
<td>12</td>
<td>3</td>
<td>5</td>
<td>4.25</td>
<td>E904</td>
<td>+160, -266</td>
</tr>
<tr>
<td>Female 65B</td>
<td>Micro-wanes range from 10-15 microns</td>
<td></td>
<td></td>
<td></td>
<td>E2127-3191</td>
<td>-</td>
</tr>
<tr>
<td>Scar 65B</td>
<td>20</td>
<td>10</td>
<td>30</td>
<td>17.25</td>
<td>E3670</td>
<td>+2713, -1543</td>
</tr>
<tr>
<td>Circle 65B</td>
<td>14</td>
<td>75</td>
<td>125</td>
<td>91.07</td>
<td>E19 376</td>
<td>+7219, -3419</td>
</tr>
<tr>
<td>Circle 65B</td>
<td>14</td>
<td>110</td>
<td>180</td>
<td>125.74</td>
<td>E26 753</td>
<td>+11545, -3349</td>
</tr>
</tbody>
</table>

Table 2 Quartz microerosion data from seven petroglyphs, at Woodstock 65B and Spear Hill 7 and 9, eastern Pilbara. Micro-wane dimensions in microns.
marginal superimposition over a non-Woodstock anthropomorph (Figure 8). The latter provided a series of twelve micro-wane width measurements with a mean value of 4.25 µm (range 3.0–5.0 µm). This corresponds to an estimated age of E904 (+160–266) years BP. At the western base of site 7, a prominent group of three female anthropomorphs includes one particularly recent example. Although no quantitative data were collected from it, it appears to be about three times as old as the nearby ‘1881’ date, having been made about E350 years ago (Table 2).

**DISCUSSION**

Although Pilbara petroglyphs, long thought to be of great antiquity, have attracted European interest for at least 160 years, until now their age has remained entirely conjectural. This paper has, however, demonstrated a standardised method capable of routinely yielding credible age estimates for individual motifs in the granite-dominated eastern Pilbara. This development was facilitated by exploiting geochemistry and micro-geomorphology to date rock art directly, based on the theory of micro-wane formation (Bednarik 1992). The discovery of engraved historical dates (Bednarik 2000b) has now made it possible to create the first microerosion calibration curve for the Pilbara (Figure 6) and use it to estimate the ages of older petroglyphs (Figure 9). The motifs analysed comprise a fairly random selection, although there was perhaps some bias in favour of very young and very old examples, to acquire an initial appreciation of the time depth represented by a few of the rock art sites in the Pilbara.

Given the tendency of archaeologists to misinterpret or over-interpret dating evidence (Bednarik 1996; Watchman 1999), the data presented in Figure 9 require qualification:

1. They do not constitute secure and precise datings. Substantial tolerances are attached to each age, reflecting the spread of the primary data. The true ages of the motifs dated do not necessarily lie within the tolerance values, although this is highly probable.

2. The reliability of each result is largely dependent on the number of micro-wane measurements made.

3. The calibration curve the age estimates listed in Table 2 are based on is tentative and may need to be refined, although there is little prospect for such refinement in Australia. It may come from comparative data from similar arid regions in other continents. This possibility is currently under investigation.

4. To obtain reliable ages by microerosion analysis two or more calibration curves from two or more minerals are desirable. Therefore, a calibration curve for feldspar should be
established for the Pilbara to render the ages in Table 2 more reliable and precise.

5. Crystalline quartz occurs in different forms. While their solution characteristics are unlikely to differ sufficiently to affect the rather coarse resolution of the method described above, this assumption should be tested by analysing surfaces of known age but different quartz types.

6. Much Pilbara rock art occurs on plutonic or extrusive igneous rocks such as gabbro, dolerite and basalt, making analysis of the microerosion behaviour of pyroxene, augite and olivine very useful for an expansion of the dating program described above. I plan to attempt this shortly.

7. The preliminary dates in Table 2 cannot be used to interpret archaeological traditions, occupation duration, or any of the other types of archaeological constructs often extracted from rock art. The few determinations now available tell us nothing about population densities, artistic trends, 'styles' etc. The rock art of the Pilbara may yield much older dates in due course, for instance from cupules.

It is likely that adverse climatic conditions during the Last Glacial Maximum, 20 000 – 15 000 BP, depopulated ecologically marginal regions, such as much of the Pilbara. This does appear to be reflected in its rock art, which indicates a lengthy period of very little, perhaps no, petroglyph production during the final Pleistocene, from the LGM to the establishment of present sea level in the early Holocene. The few age estimates presented here support such a scenario, but it requires extensive testing, through excavation and rock art dating. Hundreds of randomly selected rock art motifs need to be dated. Fortunately, the methodology described here could secure fairly reliable age estimations from numerous motifs and sites during quite brief periods of fieldwork.

This analysis has clearly demonstrated the presence of Pleistocene rock art in the Pilbara. Indeed, it suggests that petroglyphs of such antiquity occur commonly, because deeply repatinated, entirely non-iconographic motifs such as cupules and some linear arrangements account for >20% of the region's rock art motifs. The ubiquity of Pleistocene rock art in the Pilbara has long been suspected, but until now the antiquity of the many thousands of known motifs was purely speculative. This research suggests that the Pilbara comprises not only the largest regional concentration of petroglyphs, it may also possess the world's largest surviving corpus of Pleistocene art, far larger than that in the caves of south-west Europe and older than any rock art known in the Americas or Africa. Older rock art does occur in Asia (Bednarik 1994c), but little is known about its extent. In Australia, Pleistocene rock art occurs in caves along the southern coast (Bednarik 1990) and in various northern and central regions (Bednarik 1993b), but these occurrences do not rival those in the Pilbara numerically. Finally, while rock paintings do occur in the Pilbara, they are rare and none is likely to be of Pleistocene age.
I suspect that the Pleistocene rock art tradition of Australia was brought to the continent by seafarers who arrived most probably from Timor or Roti (Bednarik 1997b, 1999; Bednarik and Kuckenburg 1999), about 60 000 years ago. It derives from earlier, but very similar rock art traditions of the Acheulian in southern Asia (Bednarik 1993c, 1994c), and resembles that of Europe’s Mousterian (Peyrony 1934: 33–36, Figure 33). While Pilbara rock art does not document the beginnings of palaeoart, it is a manifestation of a magnitude unequalled elsewhere. I hope that this paper leads to a balanced reconsideration of its importance and protection.

ACKNOWLEDGEMENTS

I thank the most senior traditional custodian of the Woodstock-Abydos region, Gordon Pontroy, for giving me permission to study and record the principal corpus of rock art considered in this paper, and for sharing with me some of his knowledge about the traditional meanings of the petroglyphs at site 65B. Thanks are also due to Julie Drew, Dr Jörg Hansen, Horst Jessen, Megan Lewis, Wolfgang Lösel and Dr Anthony Manhire, for fruitful discussions in the field; and especially to Nicholas Rothwell, for organising a return trip to the region in November 2000 to complete relevant observations.

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Dating of Pilbara petroglyphs


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The Identity of *Phyllurus milii* Bory de Saint Vincent, 1823
(Squamata: Pygopodidae: Diplodactylinae)

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Abstract – The original illustration and descriptions of *Phyllurus milii* Bory de Saint Vincent, 1823 are most likely to be based on *Nephrurus levis occidentalis* Storr, 1963, not the species to which the name *milii* has been consistently applied for nearly 180 years. In the absence of types, a neotype (WAM R34085) is designated, representing the species to which the name *milii* has been applied by all subsequent authors, both for this species and *Gekko dorrensis* Péron, 1807. The senior name is identified as a *nomen oblitum*, and the junior name a *nomen protectum*, stabilising nomenclature of this species.

The Thick-tailed or Barking Gecko, *Nephrurus milii* (Bory de Saint-Vincent, 1823) is a widespread, large and readily identifiable species of southern Australia. Although the generic name has been subject to some debate, the species having been variously assigned to the genera or subgenera *Phyllurus* (e.g., Bory de Saint-Vincent, 1823, 1825; Gray, 1845, 1867; Underwood, 1954; Russell, 1980), *Anomalurus* (Fitzinger, 1843), *Gymnodactylus* (e.g., Dumeril and Bibron, 1836; Boulenger, 1885; Zietz, 1920), *Underwoodisaurus* (e.g., Wermuth, 1965; Cogger, 1975; Cogger et al., 1983) or most recently, *Nephrurus* (e.g., Bauer, 1990; Bauer and Henle, 1994; Kluge, 1991, 1993), the species name has been consistently applied since 1823, although variously misspelt on occasion as *nilii*, *miliusii*, *myliusii*, *millius* or *milusii* (see Bauer and Henle, 1994). Since 1934 (Loveridge, 1934), the specific epithet has mostly been correctly spelt.

The species was named for Lieutenant-commander (later Baron) Pierre-Bemard Milius of Bordeaux, second-in-command of the corvette *Naturaliste*, one of two original ships of the French Baudin Expedition of 1800–1804 to Australian waters, with Bory de Saint-Vincent himself, also of Bordeaux, being one of two zoologists on the same ship (Cornell, 1974). Bory de Saint-Vincent (1825, 1828) credited Milius with the discovery of the species, and for providing the colour plate drawn from life which accompanies the description. There is no evidence that Milius visited Australia, and more specifically the type locality (see below), other than with the Baudin Expedition.

Bory de Saint-Vincent’s description of this species was published in a popular encyclopedia of natural history several years after the premature death of Francois Péron (zoologist on the other ship of the Expedition, the Géographe) who had been preparing the zoological results of the Expedition for publication. The name appears three times in the encyclopedia, with a text account in volume 7 (Bory de Saint-Vincent, 1825: 183–184), another account in volume 13 (Bory de Saint-Vincent, 1828: 464–465), and a plate in the atlas, numbered the last volume in the series. Brygoo (1991) stated that the plate, although included in a volume with a title page date of 1831, was actually published as the first livraison of this volume in July 1823. Consequently, the plate validates the name, which must be regarded as published in 1823, with the illustrated specimen the holotype.

Two large gecko species of similar proportions coexist in the Shark Bay region, including both Bernier and Dorre Islands: *Nephrurus milii* and *Nephrurus levis occidentalis* Storr, 1963 (Storr and Harold, 1978). As no type material can be identified (see below), the identity of the gecko named by Bory de Saint-Vincent must be based on his description and the accompanying plate, and primarily on the latter. Bory de Saint-Vincent (1825) stated:

*PHYLLURE DE MILIUS, Phyllurus Milius, N. (V. pl. de ce Dict.) Notre ancien et illustre ami le capitaine de vaisseau Milius, ci-devant gouverneur de Mascareigne, maintenant chargé du bonheur de la Guiane française, a découvert cette espèce dans l'Australasie sur les rives de la baie des Chiens-Marins; nous lui en devons la figure et la description. Plus petite que la précédente, mais proportionnellement plus haute sur jambes, sa tête est obtuse, sa couleur d'un rouge de brique en dessus, qui ne permet que difficilement de la distinguer sur la terre rougeâtre où elle se tenait. Une sorte de demi-collier noir à trois bandes la rend fort remarquable, ainsi que la forme obtuse de sa...*
Our old and renowned friend, captain Milius, former governor of Madagascar, lately charged with the goodwill of French Guiana, discovered this species in Australia on the shores of Shark Bay; we owe to him the figure and the description. Smaller than the previous *Phyllurus Cuvieri*, *Phyllurus platurus*, but proportionally taller on the limbs, its head is blunt, its color of a brick red above, which only allows it to be distinguished with difficulty on the reddish ground which it inhabits. A sort of black half-collar with three bands makes it very remarkable, also the blunt form of its head, and the great size of its eyes, characters by which it differs completely from the Phyllure of Cuvier. The tail is not quite so pointed, and far from being cordiform, the point which it ends in seems more remarkable than the enlarged part which is very flattened and rounded.

Bory de Saint-Vincent (1828) gives an essentially similar description that provides a few additional details (head brown; two dark marks over the hip, and scattered small white tubercles over the skin):

*PHYLLURE DE MILIUS, Phyllurus (Mili) aurantiaca, verruculosa, capite fusco, caudâ spatulatif, N; V. pl. de ce Dictionnaire*. Cette espèce, plus petite que la précédente, nous a été communiquée par le capitaine de vaisseau Milius qui la découvrit, et la dessina vivante sur les plages de la baie des Chiens-Marins. Sa couleur orangée, tirant sur la teinte de brique, lui facilitait les moyens de se tenir inaperçue à la surface du sol rougeâtre, sur lequel elle était en repos aux ardeurs du soleil. Sa tête est brune, trois
dessins transversales noires forment sur le cou comme des demi-colliers, et deux marques pareilles se voient à l'insertion de la queue qui est spatulée, mais mucronée en même temps. De petits tubercules perlés et blanchâtres couvrent le peau.

Although Bauer (1990) considered that the description was unequivocally conspecific with the animal to which the name has been consistently applied, I do not believe this to be the case. Indeed, I consider that the plate accompanying the description (Figure 1), although grotesque, is more likely to represent *Nephrurus levis occidentalis*. The general coloration of the lizard painted, with a predominance of pink tones, lack of any pale transverse bands on the tail, restriction of transverse colour elements on the body to the nape and tail base, and randomly scattered fine pale spotting (vs. transversely oriented lines of larger pale tubercles), agrees with *N. l. occidentalis* rather than *N. milii* (Figure 2; see also color plates in Storr et al., 1990). The only feature of the plate that more closely resembles the latter species over the former is the lack of a terminal knob to the tail. Given the lack of detail to morphology in the plate, this could easily be an oversight on the part of the artist.

It is clearly undesirable to destabilise over a century and a half of consistent application of the name *milii* to the Thick-tailed Gecko, over a century of consistent application of the name *Nephrurus levis* to the Smooth Knob-tailed Gecko and almost four decades of use of the subspecies name *occidentalis* for the Shark Bay population of the latter species (see Bauer and Henle, 1994, for a partial list of usage of these names), by recognising *Phyllurus milii* as a senior synonym of *Nephrurus levis occidentalis*. Stability of nomenclature is best served by maintaining current usage of the specific epithet *milii*.

No type has been previously identified for *Phyllurus milii* (Guibé, 1954; Cogger et al., 1983;
Bauer, 1990; Brygoo, 1991; Bauer and Henle, 1994), and there are no identifiable Baudin Expedition specimens of either species that could represent potential types in the collection of the Museum Nationale d'Histoire naturelle, Paris (Roux-Esteve, 1979; pers. obs.), which houses other Baudin Expedition herpetological specimens, or in the Nationaal Natuurhistorisch Museum, Leiden, which received some of the Baudin Expedition herpetological specimens on exchange (pers. obs.). It is possible that the specimen drawn by Milius was released or discarded following completion of the drawing. Hence, the opportunity exists to designate a neotype concordant with current usage to fix the name.

Consequently, I designate Western Australian Museum specimen R34085, from Bernier Island, Shark Bay, as neotype of *Phyllurus milii* Bory de Saint-Vincent, 1823. The mature, but reproductively inactive female (Figure 2A), with snout-vent length 93 mm, is typical of the species to which the name has been subsequently applied, and is from a locality commensurate with the original type locality. Bernier and Dorre Islands were visited by the Baudin Expedition between 28 June and 11 July, 1801 (Cornell, 1974). The only other Shark Bay site at which the Baudin Expedition landed was Peron Peninsula, between 18 and 22 March, 1803 (Cornell, 1974).

One other action is necessary to stabilise nomenclature of this species.

Although François Péron did not live to complete the zoological results of the Baudin Expedition, he
did include in his general account of the expedition (Péron, 1807) a brief preliminary comment on three lizard species collected by the Expedition during its time at Bernier and Dorre Islands. One of these was a gecko, named by Péron *Gecko Dorreensis*. The latter name was accompanied only by a measurement (“10 à 13 centimètres (4 à 5 pouces)”). As Péron reported only a single gecko species collected at Shark Bay by the Baudin Expedition, it is likely that Bory de Saint-Vincent and Péron’s names apply to the same large species. Although generally regarded as a *nomen nudum* (Douglas and Ride, 1962, Cogger et al., 1983, Bauer and Henle, 1994), the provision of a diagnostic measurement validates the name for the purposes of nomenclature. In order to stabilise application of the name, I further designate WAM R34085 as neotype of *Gecko dorreensis* Péron, 1807.

As *mili* has been used as the valid name for the species to which both names apply, by over ten authors in more than 25 publications over the previous half-century (see Bauer and Henle, 1994 for list), while *Gecko dorreensis* has not been used as the valid name for this taxon since its first publication, I consider *Phyllurus mili i* a *nomen protectum* and *Gecko dorreensis* a *nomen ablibitum*. This action is taken in accordance with Article 23.9.1 of the Fourth Edition of the Code of Zoological Nomenclature. This stabilises usage of the name *mili* for this species by preventing use of the senior synonym.

ACKNOWLEDGEMENTS

I thank I. Ineich and M. Hoogmoed for assistance during my visits to the Paris and Leiden collections in search of Péron’s herpetological collections, and L. Smith for the loan of the neotype. The Australian Museum Photographic Department provided Figure 1, and Allen Greer provided Figure 2B.

REFERENCES


Identity of *Phyllurus milii*


*Manuscript received 30 October 2000; accepted 6 June 2001.*
The feasibility of using body proportions in Western Australian varanids (Varanus) as a method for determining a specimen's sex

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Abstract - The literature suggests that varanids are sexually dimorphic based on an array of morphometric variables. Brana (1996) reports that for lacertid lizards, size-corrected abdominal length is always larger in females and head lengths are always larger in males. Thompson and Withers (1997) reported a similar trend for some Western Australian varanids. This study examined the possibility of using a ratio of abdominal length and head length to determine the sex of varanids caught in the field. Although there are statistically significant differences in the mean ratio of abdominal length and head length for males and females for seven species of varanids in the subgenus Odatria, overlap in the ratio between males and females is too large for this to be a useful measure by itself. This ratio might, however, be useful when combined with other techniques (such as everting hemipenes) to improve the probability of determining the sex of wild-caught specimens. Ratios of abdominal length and head length for varanids in the subgenus Varanus do not differ between sexes.

INTRODUCTION

Sexing varanids in the field can be a problem. Often males of some large varanid species (e.g., Varanus gouldii or V. mertensi) will evert their hemipenes when they are first caught, clearly indicating that these specimens are males. However, if a particular specimen does not show its hemipenes one cannot assume it is a female, as it could be a male that did not evert its hemipenes. Placing pressure on the ventral surface of the tail near where the distal end of where the hemipenes would be and moving the pressure forward can often forcibly evert hemipenes. With practice, this can be a useful method of determining the sex of varanids in the field. However, it has the same problem as alluded to earlier, if a hemipenis is not everted then you cannot be confident that the specimen is a female. For some larger species (e.g., V. mertensi) hemipenes cannot be everted with pressure applied by the fingers. Reliance on eversion of hemipenes can also be a problem for the inexperienced field worker because of the existence of hemiclitores in females. For some species these structures are partly eversible, and may be quite large (Ziegler and Böhme, 1997) and can easily be confused with hemipenes.

For some goanna species in the subgenus Odatria, scalation at the base of the tail differs between sexes, with males having enlarged, spinose, postcloacal scales [e.g., V. scalaris, V. tristis, V. glauerti, V. pilbaraens, V. glebopahna (Storr et al, 1983; Sweet, 1999)]. Again, for the inexperienced field worker, a male and a female of the same species may be required for comparative purposes to ensure the correct determination of a specimen's sex.

Shea and Reddacliff (1986) and Davis (1991) report ossifications in hemipenes for some varanid species [V. komodoensis, V. gilleni, V. varius, (Shea and Reddacliff, 1986); V. dumerili (Davis and Phillips, 1991); V. giganteus (N. Heger, personal communication); V. eremius, unpub data] can be detected in radiographs. Although a useful strategy for sexing mature adults, it is of no value when varanids need to be sexed in the field or are juveniles. Similarly, Morris et al. (1998) and Schildger et al. (1999) report the use of ultrasound to sex juvenile V. komodoensis and adult V. gouldii and V. indicus respectively, but again this is not a useful strategy in the field because of the equipment requirements.

Thompson and Withers (1997) report Western Australian varanids to be generally sexually dimorphic based on an array of logarithmically transformed body dimensions. However, this method of sexing varanids is of limited value in the field because of the difficulty associated with measuring an array of head and limb dimensions of live and potentially stressed animals. Brana (1996) suggests that for some lacertid lizard species, males have longer heads than females, and females have longer abdomens than males. If this were true for varanids the measurement of a small number of body dimensions could be used to determine the sex of specimens in the field. The objective of this
study was to examine the potential of using the ratio of selected body dimensions to determine the sex of varanids in the field.

MATERIALS AND METHODS

Head and abdomen length and head width were measured for 66 *V. caudolineatus*, 50 *V. eremius*, 23 *V. storri*, 33 *V. brevicauda*, 23 *V. gilleni*, 27 *V. acanthunis*, 45 *V. tristis*, 22 *V. mitchelli*, 47 *V. scalaris*, 33 *V. rosenbergi*, 21 *V. giganteus*, 72 *V. gouldii*, 21 *V. mertensi*, 26 *V. glauerti*, 10 *V. panoptes panoptes* and 28 *V. glebopalma* specimens that were sexually mature in the Western Australian Museum collection. In addition, 13 *V. indicus* from the Queensland Museum collection were also measured. Head length (HL) was measured from the rear of the tympanum to the front of the snout, abdomen length (BL) was taken as the distance from the point where the fore leg joins the body to the cloaca and head width (HW) was the greatest lateral distance across the head. All measurements were done with vernier callipers to the nearest tenth of a millimetre.

Sex was determined by dissection and examination of the gonads. Juveniles and specimens that had their gonads missing or damaged were not included in the study. A $t$-test was used to determine statistically significant differences between mean values for the ratio BL/HL between sexes for each species. The statistical confidence limit was set at $0.05$.

<table>
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<td>3.446</td>
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<td>2.473</td>
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<td>3.398</td>
<td>3.265</td>
<td>3.531</td>
<td>3.229 - 3.615</td>
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</tr>
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</table>
RESULTS
The ratio of BL/HL differs significantly between sexes for 7 (V. acanthurus, V. caudolineatus, V. gilleni, V. glebopalma, V. micheli, V. scalaris, V. storri) of the 17 species examined, and the ratio HL/HW differs significantly between sexes for V. brevicauda. All species that have a mean BL/HL or HL/HW ratio that is different for males and females belong to the subgenus Odatria. However, these ratios do not differ significantly for several other species in the Odatria (V. erenius, V. glauerti and V. tristis). For species with a significant difference between sexes, the ratio of BL/HL is greater for females than males indicating that females generally have longer abdomens and males have longer heads or both. BL/HL ratios overlap significantly between sexes for each of these 7 species (Table 1). Ratios of BL/HL did not differ significantly for any species in the subgenus Varanus. For V. brevicauda, the ratio of BL/HL does not differ significantly between males and females but the ratio of HL/HW does differ significantly between sexes with females having the higher value (Table 1).

DISCUSSION
Mean values for the ratio of BL/HL differ significantly for 7 of 12 species in the subgenus Odatria. Comparatively longer abdomens in females and longer heads in males for some goanna species are consistent with findings of Brana (1996). However, because ratios of HL/BL (and HL/HW for V. brevicauda) for males and females are not mutually exclusive, the ratio by itself cannot be used as an indicator of a specimen's sex. BL/HL ratios cannot be used to determine sex of any species in the subgenus Varanus. Sweet (1999) provided a useful technique to sex V. glauerti and V. glebopalma. The size of post-cloacal scales for male V. glauerti and V. glebopalma are larger than those in females. Post-cloacal scales of females are larger than those in adjacent areas but not as large as those found on males. Diagrams of scales are provided for both sexes enabling comparison to be made. Storr et al (1983) provides a diagram of enlarged post-cloacal scales for male V. scalaris, V. tristis, V. glauerti and V. pilbarensis, however, no indication is provided for the scale size of females. Post-cloacal scales for these species can also be enlarged and an inexperienced field worker can confuse a female for a male without both sexes being available for comparison.

The ratio of BL/HL can at best provide an indication of the sex of some Odatrian specimens caught in the field but it should not be relied upon as BL/HL ratios overlap between sexes. The ratio of BL/HL when used in conjunction with the non-protruberance of hemipenes and the size of post-cloacal scales improves the capacity to predict a specimen's sex in the field.

ACKNOWLEDGEMENTS
Thanks to Ken Aplin and Laurie Smith, and the Western Australian Museum for providing access to the varanids in the Western Australian Museum collection. Eric Pianka provided valuable comments on an early draft.

REFERENCES

Manuscript received 1 February 2001; accepted 6 June 2001.
The Mardo: an examination of geographic variation in morphology and reproductive potential in *Antechinus flavipes* in southwestern Australia

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Abstract — The locality of Western Australian Museum specimens of *Antechinus flavipes* from southwestern Australia exhibits a marked disjunction in the species distribution. The northern distribution is characterised by females that have 10 nipples, while the southern distribution has females with 8 nipples; the two distributions come into close proximity east of Albany. Strong sexual dimorphism exists in both external and cranial variables within the two distributions. Although the cranial and external variables of each sex do not differ significantly between populations, multivariate analyses indicate that females of the two distributions show a strong separation in cranial variables on the first canonical variate. Variation in reproductive potential, as evidenced by differing nipple number, and molecular genetic studies of congeners in eastern Australia indicate the presence of cryptic species in *Antechinus*, suggesting a molecular examination of the two distributional groups in Western Australia is warranted.

INTRODUCTION

The dasyurid marsupial genus *Antechinus* is represented in Australia by ten species (van Dyck and Crowther, 2000), only one of which, *A. flavipes*, occurs in Western Australia. The genus is the best researched of Australia’s carnivorous marsupials with many significant features of their biology summarised by Lee and Cockburn (1985). All members of the genus are monoestrous and polyovular, with males exhibiting mass mortality after the short breeding season (Woolley, 1966). *A. flavipes* is commonly known as the Yellow-footed Antechinus in eastern Australia (van Dyck, 1998), but in Western Australia, where it does not have yellow feet, it is called the Mardo; some biologists recognising it as a distinct subspecies, *A. f. leucogaster* (Wakefield and Wameke, 1967).

The detailed examination of geographic variation in nipple number of females within *Antechinus* (Cockburn et al., 1983) brought to prominence the reproductive and possible taxonomic variation in the genus in the diverse habitats of eastern Australia. Recent re-examination of *Antechinus* in eastern Australia (Dickman et al., 1998; Sumner and Dickman, 1998) has highlighted the complex nature of the systematics within part of the genus and the confusion over the identity and distribution of some species.

In Western Australia *A. flavipes* occurs in a relatively wide array of habitats in the more mesic southwestern parts of the state. A detailed examination of the distribution of all mammals in the south west forests and adjacent regions for the Regional Forest Agreement process highlighted a major disjunction in the distribution of specimens of *A. flavipes* held in the collections of the Western Australian Museum. This disjunction occurred between the northern and southern forest blocks where no specimens were available from a broad expanse of forest in the region south of Collie. It was also known that nipple number varied across the range of *A. flavipes* distribution in Western Australia (Dell, personal communication).

This paper documents the variation in both reproductive potential, as reflected by nipple number, and morphology of the populations that represent the northern and southern sections of the distribution of *A. flavipes*.

MATERIALS AND METHODS

All specimens used in this study were from the Western Australian Museum’s mammal collection. An examination of 101 female *A. flavipes* was undertaken to determine nipple number and external characteristics, while a total of 52 (29 male, 23 female) individuals from across the range of *A. flavipes* in Western Australia were measured for cranial variables (Table 1).

For females, nipples were counted and examined...
Table 1 Specimens examined for morphological variables. The sexes from northern and southern distributions are separated and identified by their Western Australian Museum registration number (M), their locality and the latitude (expressed as decimal degrees south) and longitude (expressed as decimal degrees east).

<table>
<thead>
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<th>Location</th>
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<td>117.3333</td>
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Results

Biogeographic Separation

The distribution of Museum specimens of A. flavipes in southwestern Australia is presented in Figure 1. The species is generally confined to the forested and woodland areas of the southwest and there are no recent specimens from the Swan Coastal Plain and in the Jarrah forest block south of Collie (33°22'S) and north of Manjimup (34°15'S). The latter feature of the distribution gives rise to the disjunct distribution evident in Figure 1.
Variation in *A. flavipes* in southwestern Western Australia

Figure 1 Distribution of specimens of *A. flavipes* in the collections of the Western Australian Museum and the biogeographic regions of southwestern Western Australia.

Reproductive Potential

Detailed examination of pouches and counts of nipple numbers were made on all female *A. flavipes* held in the collection. The distribution of females with either eight or ten nipples is presented in Figure 2. Two individuals had 9 nipples; these are also indicated in Figure 2.

All females with 8 nipples are confined to the southern moister region of WA, particularly the Warren biogeographic region, and extend as far east as Two Peoples Bay. Just north of this location the 10 nipple females reach their most southeastern limit, such that the 10 and 8 nipple distributions are in close proximity (Figure 2). The areas of the Porongurup (34°43'S) and Stirling Ranges (34°25'S) and the woodlands and forests to the northwest are the domain of the 10 nipple females.

The marked similarity between Figures 1 and 2 indicate that the disjunct distributions noted in Figure 1 correlate closely with the two different nipple forms of the species.

Morphological Variation

The analysis of both external and cranial morphology of *A. flavipes* was undertaken on the two disjunct distributions of both a northern 10-nipple population and a southern 8-nipple population. The individuals with 9 nipples were grouped geographically with the northern population.

The external and cranial morphology of *A. flavipes* shows clearly that the species is sexually dimorphic (Table 2). Nineteen and 22 of the variables in northern and southern populations, respectively, showed males significantly (*P*<0.05) larger than females. Consequently, males and females have been treated separately in all statistical analyses.

Univariate

There was strong sexual dimorphism in external morphological features measured in *A. flavipes* with males in both distributional groups being larger than females (Table 2).
For cranial variables, females were significantly smaller than males in both distributional groups of *A. flavipes* in southwestern Australia; only IP, WIB, MLPV and IPVD showed no statistically significant sexual dimorphism in either distribution (Table 2).

No significant differences were detected between males or females from the two distributions except for interorbital width [OB] where males (P<0.05) and females (P<0.01) in the southern distribution were significantly larger than their northern counterparts.

**Multivariate**

**Males**

A CVA using cranial variables and *a priori* grouping by distribution showed an overlap of the CVA scores between the northern and southern groups (Figure 3A). This analysis was based on three characters [OB, NASL, M'M'] selected by backward elimination (Table 3), but essentially the same results were obtained using the full set of 20 cranial measures. The pattern of correlation between the three selected characters and the first canonical function show that this is largely a size discriminator. There is overlap of the CV1 scores both with longitude and latitude. The Mahalanobis (D-squared) distance between the groups was 1.2346.

**Females**

A CVA using cranial variables and *a priori* grouping by distribution showed almost complete separation (only 3 individuals from each group overlapped) of the CVA scores between the northern and southern groups (Figure 3B). This analysis was based on three characters [OB, NASW, PP] selected by backward elimination (Table 3), but essentially the same results were obtained using the full set of 20 cranial measures, with no overlap of the CV scores. The pattern of correlation between
the three selected characters and the first canonical function show that this is largely a shape discriminator. The limited overlap of CVI scores with longitude (Figure 3) indicates that the differences between females in the two distributions persist over a large longitudinal range. The Mahalanobis (D-squared) distance between the group centroids was 5.363.

The difference in the variables selected for multivariate examination of males and females suggests there is a shape difference in the anterior portion of the skulls in the two sexes.

**DISCUSSION**

The geographic variation in the litter size of *Antechinus* species was first evaluated in detail by Cockburn *et al.* (1983) with an examination of *A. swainsonii*, *A. stuartii* and *A. flavipes* in eastern Australia. They showed that major geographic variation existed in the nipple number of *Antechinus* populations. In *Antechinus* species the number of young born may be in excess of the number of nipples (Woolley, 1966), however, the maximum number of young weaned into the population is the same as the number of nipples and, consequently, nipple number is an indicator of the reproductive potential of the species or population. Subsequent research on *Antechinus* has indicated that some of this variation in nipple number may be associated with specific taxonomic differences in the populations as well (Lee and Cockburn, 1985).

Our study has shown the existence of discrete northern and southern distributional groups of *A. flavipes* in southwestern Western Australia. These two groups come into close proximity in the Two Peoples Bay area east of Albany. We have also shown that the two distributions have different reproductive potential with northern and southern females having 10 and 8 nipples, respectively. This disjunction in both the species distribution and the variation in nipple number of females in the two areas indicated the need for a re-examination of the morphology of *A. flavipes* in southwestern Australia.
Figure 3 Plot of Canonical Variate 1 against longitude for (A) male and (B) female *A. flavipes* in southwestern Australia.

particularly given that Dickman *et al.* (1998) indicated that species complexes existed in *A. stuartii* and, probably, in *A. flavipes* in eastern Australia.

Cockburn *et al.* (1983) did not include populations of *A. flavipes* from Western Australia, but they did show that in eastern Australia this species was allopatric or broadly parapatric with the widespread and common Brown Antechinus, *A. stuartii*, and occurred mainly inland of the Great Dividing Range. Across the broad distribution of *A. flavipes* in eastern Australia, Cockburn *et al.* (1983) were able to identify populations with nipple numbers varying from 8 to 13 and concluded that: “Nipple number is highest at high elevations in southeastern Australia, and lowest at low latitudes and on the exposed capes and promontories in southeastern Australia.”

In Western Australia the lower nipple number distribution occurs at higher latitudes along the southwestern fringes of the state. This correlates closely with the prediction that nipple number is lower in environments where rainfall is more predictable, and higher in more strongly seasonal environments with less predictable rainfall and resources (Cockburn *et al.*, 1983; Watt, 1997). The southern distribution of *A. flavipes* is closely correlated with the Warren bioregion, a region that is characterised by the high rainfall that encompasses the tall Karri forests of southern Western Australia (Thackway and Cresswell, 1995). The drier forests and more seasonal rainfall of the Jarrah Forest bioregion subscribe the northern distribution group. This marked difference in the distributions of the two groups and their different reproductive potential indicates that *A. flavipes* has evolved different life history strategies in different environments within the forests of southwestern Australia.

Sexual dimorphism exists in both distributional groups of *A. flavipes* in Western Australia with males being larger than females in both external and cranial variables. However, males and females do not show a significant difference in morphology between the two groups. Detailed multivariate analysis of cranial morphology in females indicates that there is a shape separation in CV1 between the two distributions and that this persists over a large longitudinal range. Whatever environmental factor(s) are driving this separation appear to be acting more intensively at greater longitudes (easterly), as overlap in multivariate space occurs only between western specimens where the distributions are most widely separated latitudinally (see Figure 2).

In a detailed examination of genetic variation in *A. flavipes* across its range, Baverstock *et al.* (1982) found no variation in electrophoretically determined loci in populations from Mt Spec in north Queensland through New South Wales, Victoria and south to Adelaide, however, no Western Australian specimens were examined. This electrophoretic examination covered populations representing the two recognised but disjunct subspecies in *A. flavipes* in eastern Australia, *A. f. rubeculis* from north Queensland and *A. f. flavipes* from southeastern Australia (van Dyck, 1998). However, Sumner and Dickman (1998) found variation in two allozymes from populations from within *A. flavipes* in southeastern Australia.

Despite similarities in both external and cranial morphology in the two distributions, the separation of females in multivariate space suggests that the taxonomic status of *A. flavipes* in Western Australia is in need of re-examination at a molecular level. This would help resolve the taxonomic status of *A. flavipes* in Western Australia compared to currently recognised congeners in eastern Australia and also
as to whether a cryptic species exists in *A. flavigipes* within Western Australia, as has been determined within *A. stuartii* in eastern Australia (Dickman *et al.* 1998).

Bow (unpubl.) has shown that the variation in nipple number in the Grey-bellied Dunnart, *Sminthopsis griseoventer*, also correlated with different bioregions. In *S. griseoventer*, females with eight, seven and six nipples were recorded, but all the six and seven nipple females were confined to the Warren bioregion while other populations in the Jarrah Forest, the Swan Coastal Plain and Boulanger Island had 8 nipples. A recent re-examination of *S. griseoventer* by Crowther *et al.* (1999), including the description of a new subspecies from Boulanger Island, indicated considerable morphological variation in this species throughout its range in southwestern Australia, however, no evaluation between forms with different nipple numbers was undertaken.

The habitats in the Warren bioregion on the southern fringe of Western Australia have influenced the life history strategies of at least two small dasyurid marsupials, indicating that resources in that area are significantly different to those of the adjacent Jarrah bioregion. A separation of females in multivariate space suggests that different selection pressures are operating on this sex in the two distributions. It remains to be determined whether these differences transfer into taxonomic differences within the respective distributional groups.

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**REFERENCES**


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Nomenclatural notes on Solifugae, Amblypygi, Uropygi and Araneae (Arachnida)

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Abstract - The following replacement names are provided for several homonyms newly detected in the Solifugae: Mumaella, nom. nov. for Gluviella Lawrence, 1956; Galeodes dahlahensis, nom. nov. for Galeodellus lindbergi Roewer, 1960; Galeodes darenensis, nom. nov. for Galeodes atriluteus Roewer, 1961; Galeodes dellacaveae, nom. nov. for Galeodila sonalica Caporiacco, 1944; Galeodes gromovi, nom. nov. for Galeodes birulae Roewer, 1941; Galeodes krausi, nom. nov. for Galeodes roeweri Kraus, 1959; Galeodes laterenceli nom. nov. for Galeodellus bicolor Lawrence, 1954; Galeodes levyi, nom. nov. for Galeodes dorsalis Roewer, 1934; Galeodes mauryi, nom. nov. for Galeodila unicolor Lawrence, 1956; Galeodes sarpolensis, nom. nov. for Galeodidas parnum Roewer, 1960; Galeodes tangharzarensis, nom. nov. for Galeodida afghana Roewer, 1960; Galeodes turki, nom. nov. for Galeodes fuscus Turk, 1947; Solpuga chelicornis var. rufescens Hewitt, 1919; Solpugema whartoni, nom. nov. for Solpuga orangica Lawrence, 1942. Numerous new generic combinations are proposed for species whose genus has been previously synonymized.

Datames magna Hancock, 1888 is proposed as the type species of Arenotherus Brookhat and Muma, which is placed as a junior synonym of Eremorhax Roewer. The type species of Paragaleodes Kraepelin, 1899 is newly designated as Galeodes scalaris C.L. Koch, 1842, and Zombis Simon, 1882 is treated as a valid genus and removed from the synonymy of Paragaleodes Kraepelin, 1899. The name Eremobates legalis, nom. nov., is proposed for the Mexican species previously known as E. geniculatus (Simon). The Mesozoic amblypygid genus Protophrynus Petrunkevitch, 1913 is replaced with Sorellophrynus. Simonoonops is proposed for the spider genus Eusimonia Dumitrescu and George, 1987 (Oonopidae) which is a junior homonym of Eusimonia Kraepelin, 1899. The spider subfamily Stemodinae is replaced with Stemoidinae, nom. nov.

INTRODUCTION

Whilst compiling data for a catalogue of some of the smaller arachnid orders (Harvey, unpublished data), a number of previously unrecognized nomenclatural problems were detected which require resolution. These include the provision of replacement names for newly detected homonyms at both the generic and specific level, and the transfer of many species to different genera due to the synonymy of the genus in which they were previously placed. Other nomenclatural problems are resolved, including the provision of a type species for Paragaleodes.

Order Solifugae

Family Ammotrechidae

Genus Lelongia Mello-Leitão

Remarks

The solifuge genus Lelongia Mello-Leitão, 1938a is a junior homonym of the mammal name Caviodon (Lelongia) Kraglievich, 1930. The homonymy has little effect on solifuge nomenclature as Lelongia Mello-Leitão is currently considered a junior synonym of Procleobis Pocock, 1899, along with Saronomoides Mello-Leitão, 1938b and Paragonolpuga Mello-Leitão, 1938b (Maury, 1977).

Family Daesiidae

Genus Biton Karsch

Remarks

The synonymy of Daesia Karsch, 1880 with Biton Karsch, 1880 by Simon (1882), which has been supported by most subsequent authors, necessitates some new combinations which to my knowledge have not been previously formally transferred from Daesia to Biton: Biton fallax (Borelli, 1925), comb. nov., B. planirostris (Birula, 1941), comb. nov., B. rossicus (Birula, 1905a), comb. nov., B. turkestanesus (Roewer, 1933), comb. nov., B. tunetanus algeriensis (Kraepelin, 1900), comb. nov. and B. villiersi (Vachon, 1950), comb. nov.
Birula (1936) placed *Bitonissus* Roewer, 1933 as a subgenus of *Daesia*, but in fact the valid generic name should be *Biton*. I here transfer the two species currently referred to *Bitonissus* to *Biton* (*Bitonissus*): *Bitonissus* schelkovnikovi Birula, 1936, comb. nov. and *B. (B.) xerxes* (Roewer), comb. nov.

**Genus Blossia Simon**

Remarks

The synonymy of *Blossiola* Roewer, 1933 with *Blossia* Simon, 1880 by Wharton (1981) requires the transfer of several species to the latter genus, many of which have not been previously formally placed in *Blossia*:


**Genus Gluviaella Lawrence and Mumaella, nom. nov.**

Remarks

*Gluviaella* Lawrence, 1956 is a junior homonym of another solifuge genus, *Gluviella* Caporiacco, 1948, and is here replaced with *Mumaella*, nom. nov. The sole species attributed to *Gluviella* Lawrence, G. *robusta* Lawrence, 1956 from Afghanistan, is here transferred to *Mumaella*: *Mumaella robusta* (Lawrence, 1956), comb. nov.

Etymology

The generic name honours the late Martin H. Muma (1916–1989) who made many significant contributions to the taxonomy and biology of solifuges. It is feminine in gender.

**Genus Hemiblossia Kraepelin**

Remarks

The synonymy of *Parablossia* Roewer, 1933 with *Hemiblossia* Kräepelin, 1899 by Wharton (1981) requires the transfer of *P. tana* Roewer, 1933 to *Hemiblossia*, resulting in a new combination: *H. tana* (Roewer, 1933), comb. nov.

**Family Eremobatidae**

**Genera Eremorhax Roewer, Arenotherus Brookhart and Muma, and Eremopus Roewer**

Remarks

Roewer (1934) described numerous new eremobatid genera from the Americas, including *Eremorhax* Roewer with the type and only species, *Datames magna* Hancock, 1888. Although the types of this species from Laredo, Texas, are apparently lost (Muma, 1951, 1970), Roewer (1934) had access to five specimens, two males and three females, from Texas that he identified as *E. magnus*. The genus *Eremorhax* was later enlarged by Muma (1951, 1970) with the synonymy of *Eremopus Roewer, 1934 (type species *Eremopus montezuma* Roewer, 1934 by original designation), Eremocosta Roewer, 1934 (type species *Eremocosta gigas* Roewer, 1934 by original designation), and *Eremacantha* Roewer, 1934 (type species *Eremacantha robusta* Roewer, 1934 by original designation). *Eremorhax* was made the type genus of Eremorhaxinae Roewer, 1934, although this subfamily was later synonymized under Eremobatinae Kräepelin by Muma (1951).

Brookhart and Muma (1987) discussed the identity of the species described as *E. magnus* (Hancock, 1888) by Roewer (1934), concluding that it was not conspecific with the species described and illustrated by Hancock (1888) and Muma (1951). Rather, they considered it a representative of the genus *Eremobates* Banks, but did not speculate any further on its identity. They then placed *Eremorhax* Roewer as a junior synonym of *Eremobates* Banks, 1900, and described a new genus, *Arenotherus* Brookhart and Muma, 1987 for *Datames magna* Hancock, 1888 and several other species. Although they consistently referred to the new genus as accommodating those species previously placed in the *Eremorhax magnus* group of Muma (1951), they did not specify a type species, in contravention of Article 13(b) of the International Code of Zoological Nomenclature, 3rd edition. The remaining species previously placed in *Eremorhax* were transferred to *Eremopus* by Muma (1989).

The lack of a type designation for *Arenotherus* was clearly a lapsus by Brookhart and Muma (1987), and I hereby designate *Datames magna* Hancock, 1888 as type species (new designation), as they so obviously intended.

In addition, when Brookhart and Muma (1987) discovered that Roewer (1934) had misidentified the type species when describing the genus *Eremorhax*, they were required by Article 70(b) of the International Code of Zoological Nomenclature...
then in effect (3rd edition) to request the Commission to resolve the case. Article 70.3 of the 4th edition of the Code (International Commission on Zoological Nomenclature, 1999) gives authors the power to designate as type species that species which best serves stability and universality – either the nominal species previously cited as type species, regardless of misidentification, or the species actually involved which was wrongly named in the type fixation – without application to the Commission. Designation of the nominal species previously cited as the type species would render Armotherus Brookhart and Muma (1987) as a junior synonym of Eremorhax. Designation of the species actually involved would render the misidentified specimens available to Roewer (1934) as representing the type species. The identity of these specimens is unclear and my attempts to locate the material have proved fruitless – Roewer (1934) did not state from which institution they were borrowed, and they were not part of Roewer’s collection now lodged in Naturmuseum Senckenburg, Frankfurt (Zilch, 1946). However, Brookhart and Muma (1987) did state (p. 1) that Roewer’s description fitted a species of Eremobates but without access to these specimens it will be difficult to determine their identity.

In the interests of stability, I here propose that the first option is the best solution and I here designate Datames magna Hancock, 1888 as the type species of Eremorhax, regardless of the misidentification made by Roewer (1934). This automatically places Arenotherus as a junior objective synonym of Eremorhax Roewer, 1934 (syn. nov.). The following species are here referred to Eremorhax:


In addition, Eremopus Roewer, 1934 is here found to be a junior homonym of the copepod genus Eremopus Brady, 1910. However, a replacement name is not needed for Roewer’s name because Eremopus currently has two junior synonyms, Eremocosta Roewer, 1934 and Eremacantha Roewer, 1934 (Muma, 1951, 1970), of which Eremocosta is here selected as the valid name. The type species of Eremocosta, E. gigas Roewer, is well defined and the holotype is an adult male lodged in Naturmuseum Senckenburg, Frankfurt, Germany (Muma, 1970), whereas the holotype of the type species of the other synonym, Eremacantha, E. robusta Roewer, is an immature specimen (Muma, 1970) whose specific identity may never be known with certainty.

Gluvia nigrimanus Pocock, 1895 was originally described from a specimen “probably from Meshed, Afghanistan” – which probably represents Mashhad, Iran – but this locality was doubted by Muma (1970), as no member of the Eremobatidae is known from outside of the New World. After examining the male holotype lodged in the Natural History Museum, London (BMNH), Muma (1970) treated this species as a synonym of Eremorhax magnus, but Brookhart and Muma (1987) removed it to the “striatus species-group”, which is here included in the genus Eremocosta.

The following species are here placed in Eremocosta:


Simon (1879) redescribed Gluvia genericulata C.L. Koch, 1842 under the name Datames genericulatus (C.L. Koch), based upon a female in MNHN from Mexico. Roewer (1934) recognized that this specimen was misidentified and utilised the name Eremocosta genericulata (Simon). This species was considered valid by Muma (1970) who reexamined the holotype and transferred it to the genus Eremobates. Unfortunately, Roewer’s action contravenes Article 49 of the International Code of Zoological Nomenclature. I hereby provide the replacement name Eremobates legalis, nom. nov.

Etymology
The specific epithet refers to the use of the International Code of Zoological Nomenclature to resolve this problem (legalis, Latin, according to law).

Family Galeodidae

Genus Galeodes Olivier

Remarks
The synonymy of Galeodarus Roewer, 1934, Galeodellus Roewer, 1934, Galeodesma Roewer, 1934, Galeodesmus Roewer, 1934, Galeodibus Roewer, 1934, Galeodius Roewer, 1934 and Galeodorla Roewer, 1934 with Galeodes Olivier, 1791 by Turk (1960) requires the formal transfer of numerous species to Galeodes:

Galeodes adamsi (Turk, 1947), comb. nov., G. ater (Roewer, 1960), comb. nov., G. atriluteus (Roewer, 1941), comb. nov., G. atrospinitus (Roewer, 1941),

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In addition, Turk's synonymy has created a number of junior secondary homonyms, a salutary lesson to all taxonomists to avoid using identical species-group names in closely related genera. The merit of Turk's synonymies are readily apparent, although future taxonomic work may reveal that one or more of Roewer's galeodid genera are valid for reasons other than those presented by Roewer. If these genera are ever removed from synonymy, then Article 59.4 of the International Code of Zoological Nomenclature (International Commission on Zoological Nomenclature, 1999) ensures that the original name should be revalidated. In addition, I have detected several cases of primary homonymy, which are here resolved.

Galeodes atroluteus Roewer, 1961 is a junior secondary homonym of Galeodellus atroluteus (Roewer, 1960) and is replaced with Galeodes dahlahensis, nom. nov.

Etymology
Named for the type locality, Darend, situated in Anatolia, Turkey.

Galeodila somalica Caporiacco, 1944 is a junior secondary homonym of Galeodes somalicus Roewer, 1934 and is replaced with Galeodes dellacaveae, nom. nov.

Etymology
This species, which is known only from the type locality Mogadiscio, Somalia, is named for Dr Laura Della Cave, in recognition of her research on solifuges and other arachnids.

Galeodes birulae Roewer, 1941 is a junior primary homonym of Galeodes birulae Hirst, 1912 and is replaced with Galeodes gromovi, nom. nov.

Etymology
This species, which has been found in Azerbaijan, Iraq and Turkey, is named for Dr Alexander V. Gromov, in appreciation of his research on solifuges.

Galeodes roeweri Kraus, 1959 is a junior primary homonym of Galeodes roeweri Turk, 1948 and is replaced with Galeodes krausi, nom. nov.

Etymology
This Iranian species is named for Prof. Dr Otto Kraus in recognition of his work on solifuges and other arachnids.

Galeodellus bicolor Lawrence, 1954 is a junior secondary homonym of Galeodes bicolor Roewer, 1934 and is replaced with Galeodes lawrencei, nom. nov.

Etymology
This species, which is known only from Basrah, Iraq, is named for the late Reginald F. Lawrence (1897–1987) in honour of his contributions to arachnology.

In accordance Appendix A of the International Code of Zoological Nomenclature (International Commis.sion on Zoological Nomenclature, 1999), Dr Kraus was contacted to elucidate whether he wished to provide the replacement name, to which he demurred.
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Galeodes dorsalis Roewer, 1934 is a junior primary homonym of Galeodes dorsalis Latreille, 1817 and is replaced with Galeodes levyi, nom. nov.

Etymology

This species, which is found in Israel, Saudi Arabia and Syria, is named for Dr Gershom Levy, in appreciation of his research on solifuges.

Galeodila unicolor Lawrence, 1956 is a junior secondary homonym of Galeodes (Paragaleodes) unicolor Birula, 1905b and is replaced with Galeodes mauryi, nom. nov.

Etymology

This species, which is only known from two specimens collected in Afghanistan, is named for the late Dr Emilio A. Maury, in appreciation of his contributions to arachnology.

Galeodila afghana Roewer, 1960 is a junior secondary homonym of Galeodes afghanus Pocock, 1895 and is replaced with Galeodes langkharzarensis, nom. nov.

Etymology

Named for the type locality, Darreh-Khordou near Tang-Kharzar, Afghanistan.

Galeodes fuscus Turk, 1947 is a junior primary homonym of Galeodes caspius fuscus Birula, 1890. and is replaced with Galeodes turki, nom. nov.

Etymology

This species, which is only known from the type collection made in Maharashtra State, India, is named for the late F.A. Turk, in appreciation of his research on solifuges.

Genera Paragaleodes Kraepelin and Zombis Simon

Remarks

Although Roewer (1934) treated Paragaleodes Kraepelin (1899) as a synonym of Galeodes Olivier, 1791, later authors including Birula (1938) and Turk (1960) revalidated the name and provided a more comprehensive diagnosis. However, Kraepelin (1899) did not nominate a type species and to my knowledge none has ever been designated, thus leaving the genus in a state of taxonomic limbo. Related to this problem is the status of Zombis Simon (1882) described for the sole species Z. pusiola Simon, 1882 from Israel. Kraepelin (1901) tentatively synonymized Z. pusiola with Paragaleodes scalaris (C.L. Koch, 1842), which places Zombis as a potential senior synonym of Paragaleodes if the type species of both taxa are considered to be congeneric. Kraepelin (1899) included several species in Paragaleodes and all but Galeodes barbarus Lucas, 1849 is currently included in the genus.

If G. barbarus is designated as type species of Paragaleodes, then this generic name will become a synonym of Galeodes as currently defined, and Zombis becomes available for those species currently in Paragaleodes. However, if one of the other species originally included in Paragaleodes by Kraepelin (1899) is selected as the type species, then Zombis will have priority over Paragaleodes whenever the selected type species and Z. pusiola are deemed to be congeneric. I am extremely reluctant to replace Paragaleodes with Zombis without a more detailed review of the taxonomy of galeid genera, and note that Kraepelin (1901) only tentatively synonymized Z. pusiola with P. scalaris, so the true taxonomic status of Z. pusiola is still unknown. Therefore, I propose the following solution:

I hereby designate Galeodes scalaris C.L. Koch, 1842 (new designation) as the type species of Paragaleodes, and I disregard Kraepelin’s synonymy of Z. pusiola with P. scalaris, allowing Zombis to stand as a monotypic genus until the necessary revisionary work is completed to more fully understand the identity of the names involved. If any future work upholds Kraepelin’s (1901) decision, the case should probably be submitted to the International Commission on Zoological Nomenclature to enable the retention of the better known Paragaleodes.

In addition to this problem, Galeodes (Paragaleodes) unicolor Birula, 1905b has never been formally placed in Paragaleodes: Paragaleodes unicolor (Birula, 1905b), comb. nov.

Family Gylippidae

Genus Gylippus Simon

Remarks

Although Anoplogylippus was treated as a valid genus by Roewer (1933, 1960), Birula (1913) and
Gromov and Kopdykbaev (1994) regard it as a subgenus of Gylyppus. Thus, Anoplogylippus oculatus Roewer, 1960 is here transferred to Gylyppus (Anoplogylippus): Gylyppus (Anoplogylippus) oculatus (Roewer, 1960), comb. nov.

Family Karschiidae
Genus Eusimonia Kraepelin

Remarks
The synonymy of Barrella Hirst, 1910 with Eusimonia Kraepelin, 1899 was first proposed by Birula (1938), but the type species of Barrella, B. walsinghami Hirst, 1910 has never been formally transferred to Eusimonia: Eusimonia walsinghami (Hirst, 1910), comb. nov.

Genus Rhinippus Werner

Remarks
The homonymy between the solifuge genus Rhinippus Werner, 1905 and the mammal name Rhinippus Burmeister, 1875 has to my knowledge not previously been detected. However, no replacement name is required, as the junior synonym Barrussus Roewer, 1928 can be substituted for Rhinippus Werner. Only two species are affected: Barrussus furcichelis Roewer, 1928, and B. pentheri (Werner, 1905), comb. nov.

Family Rhagodidae
Genus Rhagodes Pocock

Remarks
Although not specifically stated by Birula (1938), his treatment of R. melanopygus (Walter) as a member of the genus Rhagodes Pocock implies that he treated Rhagodella Roewer, 1933, of which the type species is R. melanopygus, as a junior synonym of Rhagodes. This synonymy seems entirely plausible, as the features which Roewer (1933) utilized to separate genera such as Rhagodella from Rhagodes are based upon minor differences in the spination of tarsi II–IV. Indeed, the status of the numerous other rhagodid genera erected by Roewer (1933) has never been fully assessed, and it is possible that the fate of many of these taxa will be as junior synonyms of Rhagodes. The synonymy of Rhagodella with Rhagodes has resulted in three new combinations, which to my knowledge have never been formally proposed:
R. ater (Roewer, 1933), comb. nov., R. metatarsalis (Roewer, 1933), comb. nov. and R. zugmayeri (Roewer, 1933), comb. nov.

Family Solpugidae
Genus Enea Roewer

Remarks
Enea Roewer, 1933 is here found to be preoccupied by Enea Walker, 1864, a genus of Lepidoptera. However, a new name is not needed to replace Enea Roewer, as the genus was synonymized with Ferrandia Roewer, 1933 by Lawrence (1954), which was described on the page preceeding Enea.

Genus Oparba Roewer

Remarks
The synonymy of Oparbica Roewer, 1934 with Oparba Roewer, 1934 by Lawrence (1966) requires the transfer of four species to Oparba, resulting in new combinations: Oparba brunnea (Roewer, 1934), comb. nov., O. asiatica (Turk, 1948), comb. nov., and O. toscona (Roewer, 1934), comb. nov.

Genera Solpuga Lichtenstein and Zeria Simon

Remarks
As discussed by Wharton (1981), Roewer (1933) erred in regarding Solpuga lethalis C.L. Koch, 1842 as the type species of Solpuga Lichtenstein, 1796, as S. lethalis was not one of the originally included species of Solpuga. Pocock (1897) appears to have been the first author to legally designate a type species for Solpuga when he nominated S. chelicornis Lichtenstein, 1796. Roewer (1933) then erected the name Solpugops for S. chelicornis and related species, which is thus a junior objective synonym of Solpuga (Wharton, 1981). The species of Solpuga sensu Roewer (1933) can be treated as members of Zeria Simon, 1879, but as noted by Wharton (1981) the type species of Zeria, Z. persephone Simon, 1879 from Algeria, may not be closely related to S. lethalis and its relatives in southern Africa. However, until the necessary taxonomic work on the African Solpugidae is completed, I hereby transfer all species previously treated as members of Solpuga sensu Roewer (1933) to Zeria, and transfer several species from Solpugops to Solpuga, to resolve the outstanding nomenclatural issues:
Solpuga angolensis (Roewer, 1933), comb. nov., S. conservatorum (Lawrence, 1964), comb. nov., S. truncata (Lawrence, 1968), comb. nov., Zeria albistriata (Roewer, 1933), comb. nov., Z. angolana (Frade, 1940), comb. nov., Z. antelopiconis (Lawrence, 1929), comb. nov., Z. atra (Roewer, 1933), comb. nov., Z. atrisoma (Roewer, 1933), comb. nov., Z. boehmi (Kraepelin, 1899), comb. nov., Z. caffra (Pocock, 1933), comb. nov., Z. lichtensteini (Pocock, 1933), comb. nov.
Nomenclatural notes on Arachnida


In addition, Solpuga chelicornis var. rufescens Hewitt, 1919 is a junior primary homonym of Solpuga rufescens C.L. Koch, 1842, which is here replaced with Solpuga chelicornis carlkochii, nom. nov. The various subspecies of Solpuga chelicornis are probably not valid (Wharton, 1981), and this subspecies may eventually be regarded as a synonym of Solpuga chelicornis.

Etymology
This South African subspecies is named for Carl L. Koch (1778–1857) who made a number of important contributions to the study of solifuges.

Genus Solpugema Roewer

Remarks
Solpuga orangica Lawrence, 1942 is a junior primary homonym of Solpuga coquinae orangicus Hewitt, 1919 and is here replaced with Solpugema whartonii, nom. nov.

Etyymology
This species, which is known from Namibia, is named for Robert A. Wharton, in recognition of his research on Namibian solifuges.

Genus Solpugiba Roewer

Remarks
The synonymy of Solpugelis Roewer, 1934 with Solpugiba Roewer, 1934 by Wharton (1981) requires the transfer of Solpugelis pictichelis Roewer, 1934 to Solpugiba, resulting in a new combination: Solpugiba pictichelis (Roewer, 1934), comb. nov.

Order Amblypygi

Genus Protothyrinus Petrunkevitch and Sorellophrynus, nom. nov.

Remarks
The amblypygid genus Protothyrinus Petrunkevitch, 1913 has been found to be a junior homonym of the amphibian genus-group name Protothyrinus Pomel, 1853, and is here replaced with the name Sorellophrynus, nom. nov. The only included species becomes Sorellophrynus carbonarius (Petrunkevitch, 1913), comb. nov.

The four recognized species of Mesozoic amblypygids are currently placed in three genera, but Dunlop (1994) suggested that Thelyphyrinus Petrunkevitch, 1913 and Protothyrinus may be synonyms of the oldest name Graeophonus Scudder, 1890. If this is confirmed by further work on the Carboniferous Amblypygi, then Protothyrinus carbonarius becomes a junior secondary homonym of the type species of Graeophonus, Libellula carbonaria Scudder, 1876, currently Graeophonus carbonarius (Scudder, 1876).

Etymology
The generic name alludes to the Mesozoic age of the type species and to the fact that the name may eventually become a junior synonym of Graeophonus (sorelle Greek, old man with one foot in the grave; and phryne, Greek, a toad, a commonly used stem amongst the Amblypygi). It is masculine in gender.

Family Charinidae

Genus Chaerinus Simon

Remarks
The synonymy of Tricharinus Quintero, 1986 with Chaerinus Simon, 1892 by Weygoldt (2000) requires the transfer of the three species originally included in Tricharinus: C. guianensis (Quintero, 1986), comb. nov., C. caribensis (Quintero, 1986), comb. nov. and C. platnicki (Quintero, 1986), comb. nov.
Order Uropygi
Family Thelyphonidae
Genus Minbosius Speijer

Remarks
The genus Minbosius Speijer, 1933 was originally erected for Minbosius kopsteini Speijer, 1933 from the Indonesian island of Ambon, to which Thelyphonus manilanus C.L. Koch, 1843 was later added (Speijer, 1936). I here formally transfer T. manilanus halmaherae Kraepelin, 1897 to Minbosius: Minbosius manilanus halmaherae (Kraepelin, 1897), comb. nov.

Order Araneae
Family Oonopidae
Genus Eusimonia Dumitrescu and Georgescu

Remarks
The spider genus Eusimonia Dumitrescu and Georgescu, 1987 is a junior homonym of Eusimonia Kraepelin, 1899 (Solifugae), and is here replaced with Simonoonops, nom. nov. The type and sole included species, E. orghidani Dumitrescu and Georgescu, 1987 becomes Simonoonops orghidani (Dumitrescu and Georgescu, 1987), comb. nov.

Family Malkaridae
Subfamily Sternoidinae, nom. nov.

Remarks
The family-group name Sternodidae was proposed by Moran (1986) for an unusual group of litter dwelling spiders from Australia comprising two genera, Sternodes Butler, 1929 and Carathae Moran, 1986. Platnick and Forster (1987) reduced the Sternodinae to a subfamily within the Malkaridae. Platnick (1997) replaced the generic name Sternodes Butler, 1929 with the name Sternoides Platnick, 1997, as the former was found to be preoccupied in the Coleoptera and Hymenoptera. I here replace the name Sternodinae with Sternoidinae as required under Article 39 of the International Code of Zoological Nomenclature, 4th edition. The type genus is Sternoides Platnick, 1997.

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Nomenclatural notes on Arachnida


Manuscript received 30 January 2001; accepted 2 July 2001.
An Eocene fossiliferous chert artefact from Beacon Island: first evidence of prehistoric occupation in the Houtman Abrolhos, Western Australia

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In the course of recent research into the survivors of the 1629 Batavia shipwreck, a significant and unusual stone artefact was found in faunal material excavated from Beacon Island (Marwick 1999). This prehistoric artefact is made from Eocene fossiliferous chert that probably derives from outcrops on the now-submerged continental shelf that were once quarried by Aboriginal stone tool makers (Glover et al. 1993: 41-42). The artefact, along with faunal material consisting of bird, fish and native and introduced mammal bones, was excavated in 1967 by a Western Australian Museum expedition led by Colin Jack-Hinton and is currently stored at the Western Australian Maritime Museum. This artefact is the first evidence of prehistoric Aboriginal occupation of the Houtman Abrolhos. It suggests that Aboriginal occupation of the Houtman Abrolhos pre-dates the isolation of the islands from the mainland and the submersion of the continental shelf at around 6 000 BP.

The Houtman Abrolhos are a group of 108 low-lying islands surrounded by extensive coral reefs located toward the edge of the continental shelf. They are about 500 km north of Fremantle and 65 km west of Geraldton, in the area 28°14'- 29°00'S, 113°35'- 114°04'E (figure 1). The islands were separated from the mainland by rising sea levels at 11 000 – 12 000 BP (Dortch and Morse 1984: 41, cf. Royal Australian Navy 1969). Archaeological surveys and excavations have been conducted in the Wallabi Group since 1963, the most recent being in 2001. The focus of most of the archaeological research in the Wallabi Group has been the submerged wreck of the Batavia. In addition to the underwater investigations, archaeologists have also conducted research into the location and character of the survivors' camps relating to the 1629 shipwreck of the Batavia (Gibbs 1992). Land based archaeological investigations into the Batavia shipwreck survivors have resulted in several surveys and excavations on West Wallabi Island and Beacon Island (Gibbs 1992). A five-day survey for prehistoric archaeological material on East and West Wallabi Islands found no indication of prehistoric Aboriginal occupation (Dortch and Morse 1985). Dortch and Morse (1985: 41) examined 'a variety of likely localities' on the two islands and were surprised at the absence of material. They were unwilling to conclude that the Houtman Abrolhos were unoccupied before European settlement and they wrote that it is 'likely that any finds there will consist of isolated stone artefacts like those from Rottnest and Garden Islands' (Dortch and Morse 1985: 41).

The artefact is a black Eocene fossiliferous chert flake with slight edge damage, a missing linear platform and a hinge termination (figure 2). Its dimensions are: 25.6 mm long by 28.1 mm wide by 4.0 mm thick. The artefact is translucent and unweathered, similar to other unweathered flakes found on Rottnest Island and excavated from Devil's Lair (Dortch 1984, Dortch 1991: figure 2.1, Hesp et al. 1999: figure 2.1, Dortch pers comm 1999). The raw material of the artefact indicates that it was procured and manufactured before around 6 000 BP when the Eocene fossiliferous chert outcrops on the outer edge of the continental shelf were submerged by glacio-eustatic sea level rise (Glover 1975, 1979, 1984: 17-18, Glover and Lee 1984: 16, Thom and Chappell 1975, Quilty 1978). Many hundreds of Eocene fossiliferous chert artefacts have been recorded at dozens of sites in the Perth
Figure 1 Map of Abrolhos Islands from Storr, Johnstone and Griffin (1986) detailing location of Beacon Island.

Basin, Leeuwin Block and Southern Ocean coast. Eocene fossiliferous chert artefacts first appear in archaeological sequences at more than c. 30 000 BP and then disappear during the Middle Holocene (Ferguson 1980, Glover 1984, Glover and Lee 1984, Glover et al. 1978, Pearce 1978).

It is unlikely that the artefact represents early European activity on the island. A firearm flint was recovered in Bevaqua’s 1974 excavations, which is probably associated with the flintlock muskets used by the Batavia survivors during the mutiny (Bevaqua 1974). Firearm flints have a distinctive wedge shape (Held 1970) that is quite different from the Beacon Island flake. The Batavia survivors may also have used tinderboxes for starting fires that include flints characteristic in morphology and raw material. The shape of the Beacon Island flake does not resemble a flint from a flintlock firearm or a tinderbox. Although flint pebbles were often used as ballast, historical records do not indicate that the Batavia ballast was salvaged and used by the survivors on the islands. European chert artefacts have been dumped with ballast in Australia (Dortch and Glover 1983, McCarthy 1958: 178). However,
the ballast materials of the *Batavia* can be ruled out as a possible flint source as they were mainly bricks (Godard 1993). There are no chert sources on the Abrolhos and the nearest source is either on the submerged continental shelf or over 80 kilometres to the north-east in the Carnarvon Basin (Glover 1975).

The artefact was recovered from the 1967 excavations at the north-east of Beacon Island in association with bird, fish and native and introduced mammal bones and fragments of Dutch ceramics, metal and glass. Unfortunately there are no extant records of the 1967 excavations except for the artefact accession labels. A tentative reconstruction of the excavations based on the accession numbers and details of subsequent excavations suggests that the artefact was recovered from a depth of 20-30 cm (Marwick 1999). The artefact's provenance at the time of recovery is of limited chronological or contextual significance because of the low stratigraphic integrity of the soil. The soil matrix is loose, sandy and frequently disturbed by the burrowing of animals, notably the seasonal nesting activity of the wedge-tailed Shearwater (Bevaqua 1974, Storr 1965, Storr *et al.* 1985).

Weathering from exposure on Beacon Island may result from the salt spray, sandblasting, high ground surface heat and bright sunlight. If the flake had been exposed to these conditions it would be deeply patinated, dehydrated, porous textured and partly desilicified, similar to other Eocene fossiliferous chert artefacts from open air sites in the south-west (Dortch 2000 Vol 2: 47). Given the extreme weathering conditions on Beacon Island and the unweathered appearance of the artefact it is likely that the artefact remained buried for long periods.

The significance of this artefact is that it shows prehistoric Aboriginal occupation of offshore islands in an area and for a period where no previous evidence exists. Dortch and Morse (1985: 42) conclude from existing archaeological data that distant offshore islands in Western Australia were occupied in prehistoric times only when the sea levels were low and when the islands were readily accessed from the present mainland. This artefact confirms the conclusion of Dortch and Morse (1985: 42) and is evidence of prehistoric human activity on Beacon Island during the glacio-eustatic sea-levels rise between 11 000 - 12 000 BP and about 5 000 BP. (Dortch and Morse 1985: 41). Future research in the Houtman Abrolhos area may reveal patterns of prehistoric occupation and raw material use similar to other areas close to the outer edge continental shelf in Western Australia as described by Dortch and Morse (1985) and Bowdler (1995).

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