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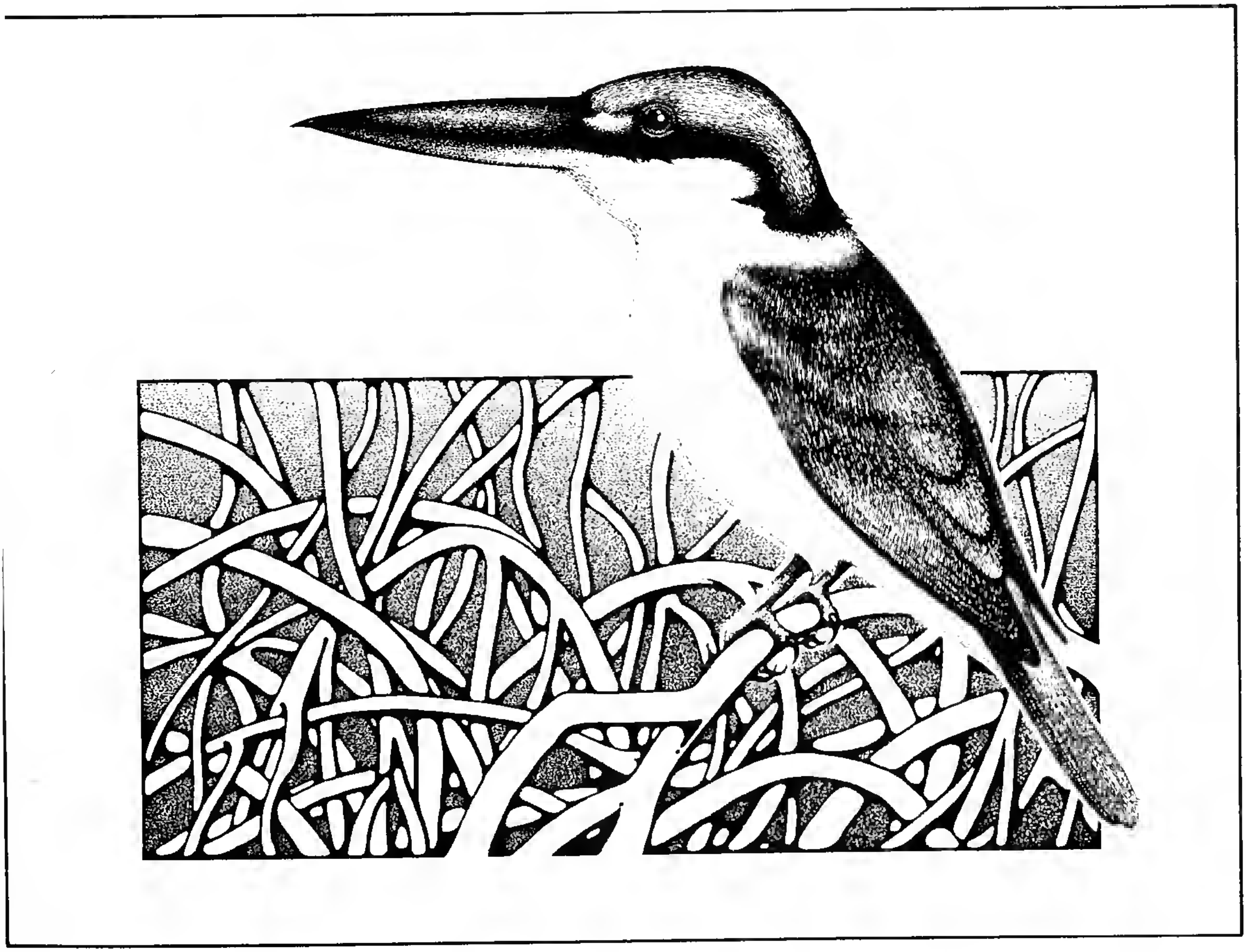

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Sminthopsis aitkeni **sp. nov.**
(Figure 2e, 11; Table 1)

Sminthopsis gilberti sp. nov.
(Figure 2c, 4b, 7, 8; Table 1)

The Editorial Sub-Committee earlier provided you with emendation slips to cover two printing errors in the paper by Kitchener *et al. Rec. West. Aust. Mus.* 1984 11 (3): 201-248.

In case you have been unable to attend to this emendation we again enclose these two slips for you to place over the headings of '***Smithopsis gilberti*** **sp. nov.**' (p. 221) and '***Smithopsis aitkeni*** **sp. nov.**' (p. 230).

Rec. West. Aust. Mus. 1983, 11 (1): 1-9

Prevalence and Intensity of *Abbreviata* Travassos (Nematoda: Physalopteridae) in the Ridge-tailed Monitor *Varanus acanthurus* Boulenger in Northern Australia

H.I. Jones*

Abstract

Four species of *Abbreviata* were recovered from the stomachs of 212 *Varanus acanthurus: Abbreviata hastaspicula* (65% infection), *Abbreviata antarctica* (8% infection), *Abbreviata confusa* (5% infection), and *Abbreviata* sp. (1% infection). *A. hastaspicula* was more prevalent in Western Australia than in the Northern Territory, and occurred at all seasons of the year, with lowest prevalence and intensity of infection from March to May.

A. antarctica was more prevalent in the central parts of the host's range and during the drier season of the year. *Abbreviata confusa* was confined to the more northerly areas, north of 18°S, and was recovered throughout the year. Worm numbers appeared to be unaffected by concurrent congeneric infection. A fourth unidentified species, similar in morphology to *A. tumidocapitis*, was recovered from two host specimens from the Kimberley. Prevalence of infection and worm intensity of *A. hastaspicula* increased with increase in host size; there was a positive correlation between adult and larval numbers in both *A. hastaspicula* (r:0.576, $P<0.001$ and *A. antarctica* (r:0.680, $P<0.05$), and there was a seasonal correlation between adult and larval numbers in *A. hastapicula*.

Introduction

The Ridge-tailed Monitor, *Varanus acanthurus,* is widespread in the arid and seasonally dry areas of northern Australia, occurring principally among rocky outcrops (Cogger 1975). The biology of this species is still poorly known, and there have been no records of its helminth parasites. This paper reports the results of a study of the prevalence, intensity and geographical distribution of the gastric nematodes in *V. acanthurus*.

Material Examined

During a study of diet and foraging in *V. acanthurus,* D. King collected worms from a large number of preserved specimens in the Western Australian and Northern Territory Museums, and it is this material which forms the basis of the present paper. Worms were collected from the stomachs of 122 specimens of *V. acanthurus* stored in the Western Australian Museum; from 86 in the Northern Territory Museum; and 4 in the Queensland Museum.

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Nematodes Examined

Abbreviata hastaspicula	WAM 34-81 – 123-81; NTM Y55-98, QM GL 1573-GL1575
Abbreviata antarctica	WAM 124-81 – 129-81; NTM Y99-109
Abbreviata confusa	WAM 130-81 – 133-81; 7-82; NTM Y110-114
Abbreviata sp.	WAM 8-82; 9-82

As the stomachs had been removed from all hosts (except those from the Queensland Museum) prior to examination, any worms present in either the oesophagus or upper small intestine would not have been recorded and in larger varanid species a significant proportion of *Abbreviata* spp. may occur in these sites (Jones 1983). *Abbreviata* spp. are however predominantly gastric nematodes, and any inaccuracies resulting from their being in other locations are unlikely to invalidate these results substantially.

Methods

All hosts had been preserved in formalin and stored in70% alcohol. Worms were cleaned, cleared in chlorolactophenol and examined under an Olympus BA 211 microscope.

Ecological terms are used according to the definitions of Margolis *et al.* (1982): *prevalence* refers to the percentage of host specimens infected with a parasite species, and *intensity* refers to the number of individuals of a parasite species in each infected host.

Results

Seventy-four per cent of *V. acanthurus* stomachs examined contained nematodes in the genus *Abbreviata* Travassos, belonging to four species. Sixty-five per cent were infected with *Abbreviata hastaspicula* Jones, 1979, 8% with *Abbreviata antarctica* (von Linstow, 1899) (syn: *A. occidentalis),* 5% with *Abbreviata confusa* (Johnston and Mawson, 1942), and 1% with *Abbreviata* sp. Two per cent of lizards contained larval or immature *Abbreviata* spp. only. The prevalence and intensity of adult and larval infections are shown in Table 1. In addition, two hosts from the Prince Regent National Park were infected with one female and one immature unidentified spirurid nematode.

Table 1 Prevalence and intensity of adult and larval *Abbreviata* species in *V. acanthurus.*

Species	Prevalence (N:212)		Intensity of Infection		Single Species Infections		Concurrent Infections (2 Spp)		Associated* Larval/Immature Prevalence		Larval/immature* Intensity	
	No.	%	Mean	Range	No.	%	No.	%	No.	%	Mean	Range
A. hastaspicula	137	64.6	21.8	1-151	121	88	16	12	92	76	14.5	1-137
A. antarctica	17	8.0	15.1	1-159	9	53	8	47	6	66	5.6	1-13
A. confusa	10	4.7	14.1	1-74	4	40	6	60	2	50	0.5	0-2
Abbreviata sp.	2	1.0	2.0	1-3	0	–	2	100	–	–	–	–

* In single species infections only.

Abbreviata hastaspicula was the most prevalent species. Infections occurred throughout the range of *V. acanthurus* (Figure 1a), in all months of the year (Figure 2a). Prevalence of infection increased with the size of the host to a snout-vent length (SVL) of approximately 120 mm, and then became constant, (Figure 3a). Prevalence of high intensity infection (>20 adult worms) also increased with host size, to an SVL of approximately 180 mm, but decreased in larger hosts (Figure 3a). Almost half the lizards (47%) infected with this species had an intensity of ten worms or less (Figure 4). Female worms (N: 207) were measured from 25 hosts; their mean length was 18.8 mm (σ4.85, range 9-32 mm). There was no relationship between worm size and intensity of infection. Seasonal abundance of larval and immature forms correlated closely with numbers of adults (Figure 5), and there was a positive correlation between increasing adult and larval numbers (r:0.576; $P < 0.001$). More than half the *A. hastaspicula*-infected lizards which contained larvae had an intensity of < six larvae. There was no significant difference ($P>0.05$) between numbers of *A. hastaspicula* in single species infections, and in those with concurrent infections of *A. antarctica*, or *A. confusa*.

Abbreviata antarctica infection was more prevalent in the Northern Territory than in Western Australia (X^2, $P<0.01$), (Figure 1b). Sixteen of the seventeen infections occurred during the drier months of the year, from April to October (Figure 2b). Intensity of infection with this species appeared to be unaffected by concurrent *A. hastaspicula* infection; there were no concurrent *A. confusa* infections. There was a positive correlation between increasing adult and larval numbers (r:0.680; $P<0.05$).

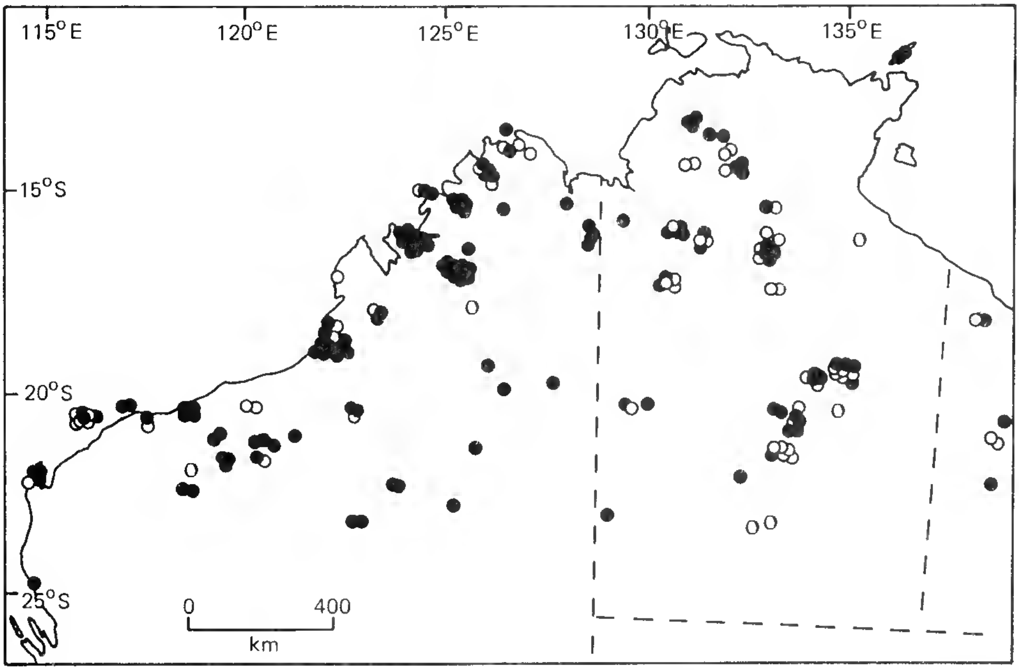

Figure 1a Geographical distribution of *A. hastaspicula* infection in *V. acanthurus* (O no infection; ● infection present).

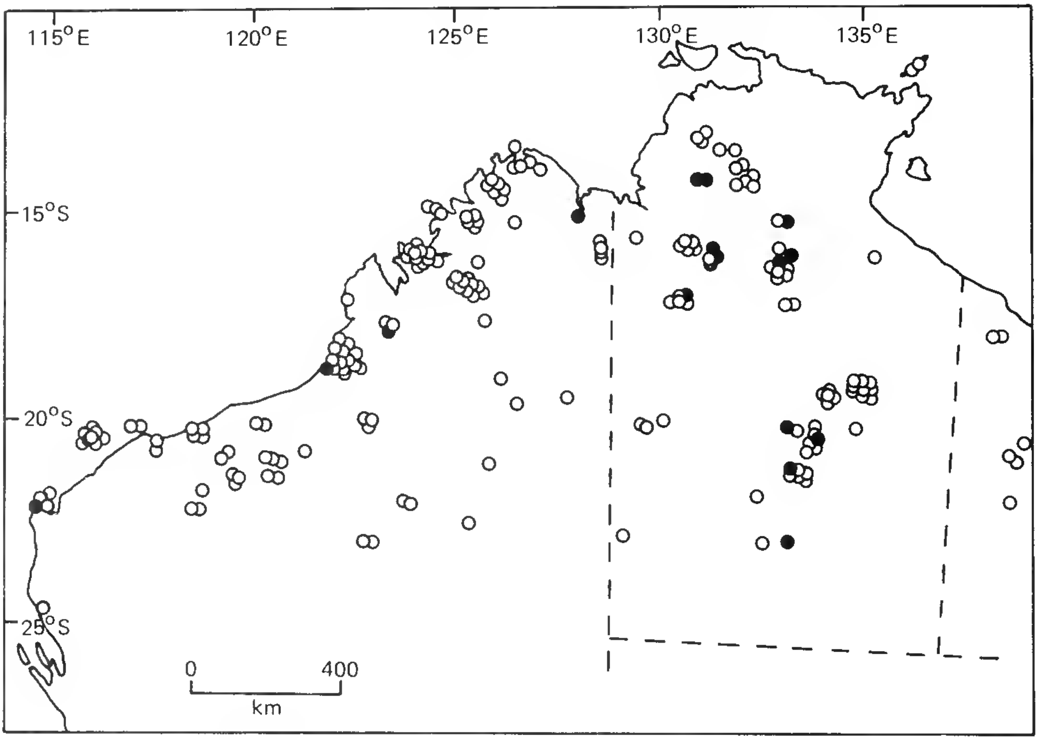

Figure 1b Geographical distribution of *A. antarctica* infection in *V. acanthurus*. (Symbols as in Figure 1a.)

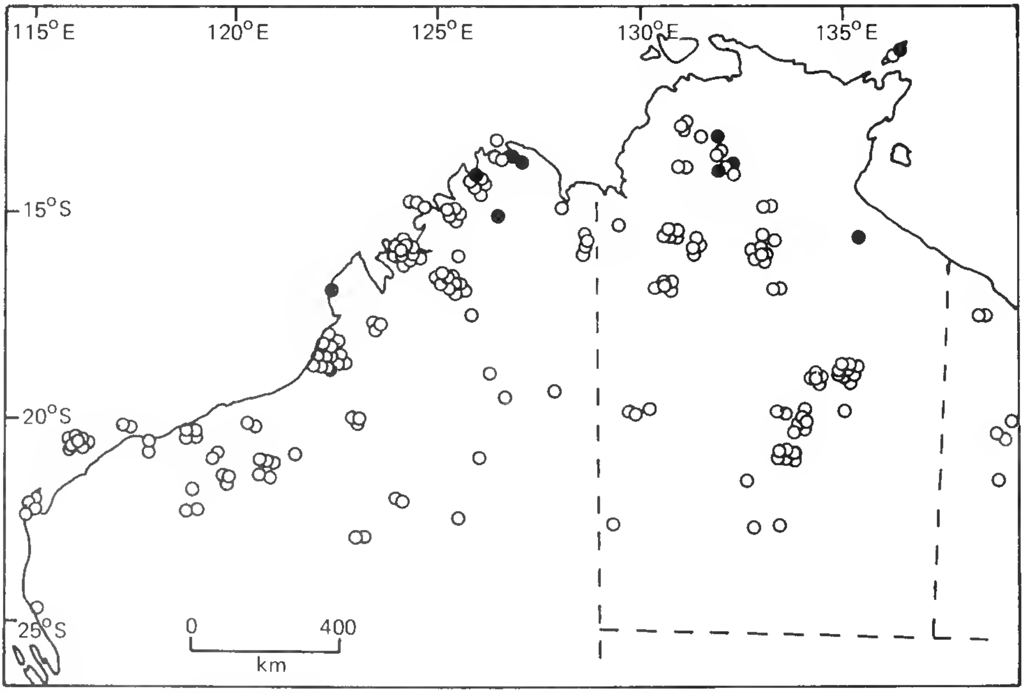

Figure 1c Geographical distribution of *A. confusa* infection in *V. acanthurus*. (Symbols as in Figure 1a.)

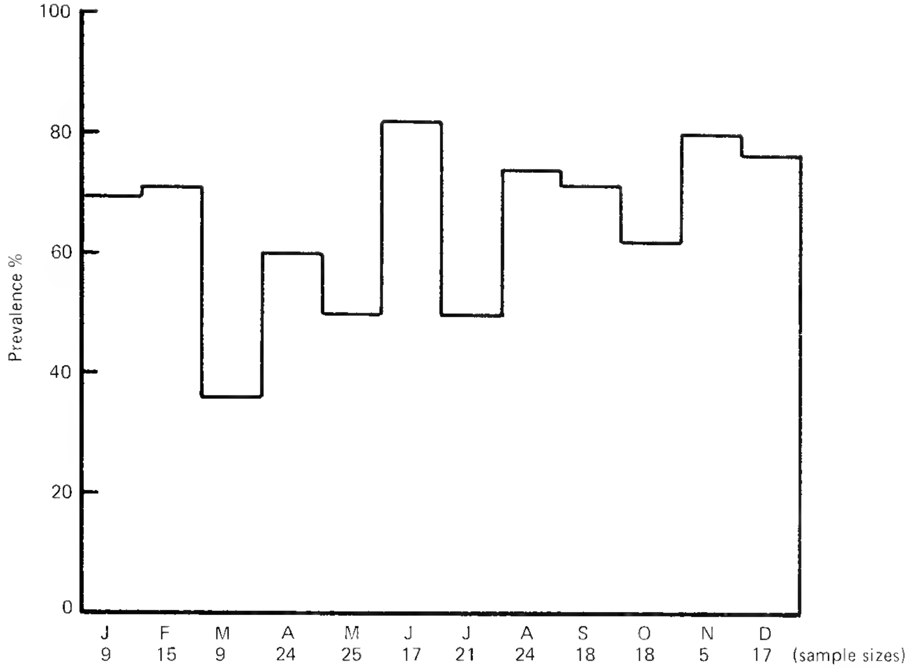

Figure 2a Seasonal prevalence of adult *A. hastaspicula* infection in *V. acanthurus.*

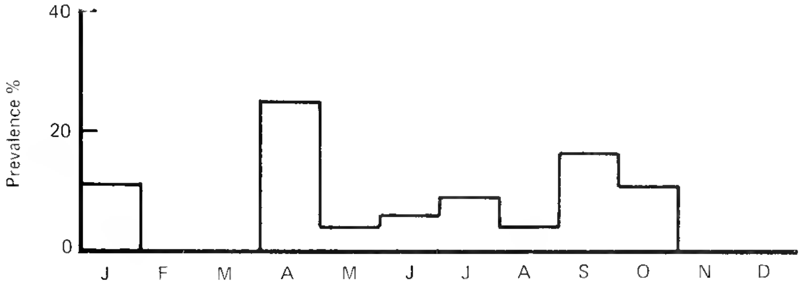

Figure 2b Seasonal prevalence of adult *A. antarctica* infection in *V. acanthurus.*

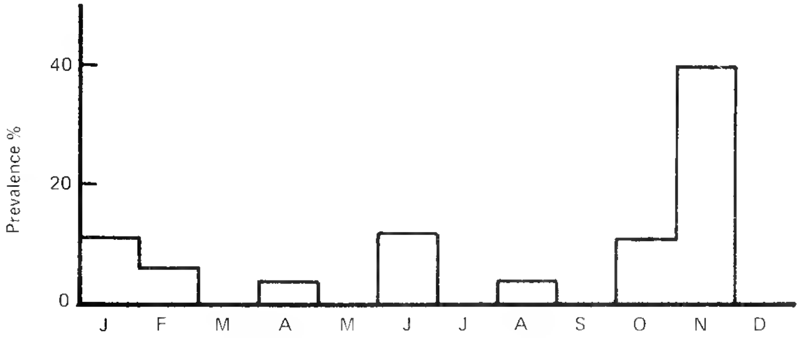

Figure 2c Seasonal prevalence of adult *A. confusa* infection in *V. acanthurus.*

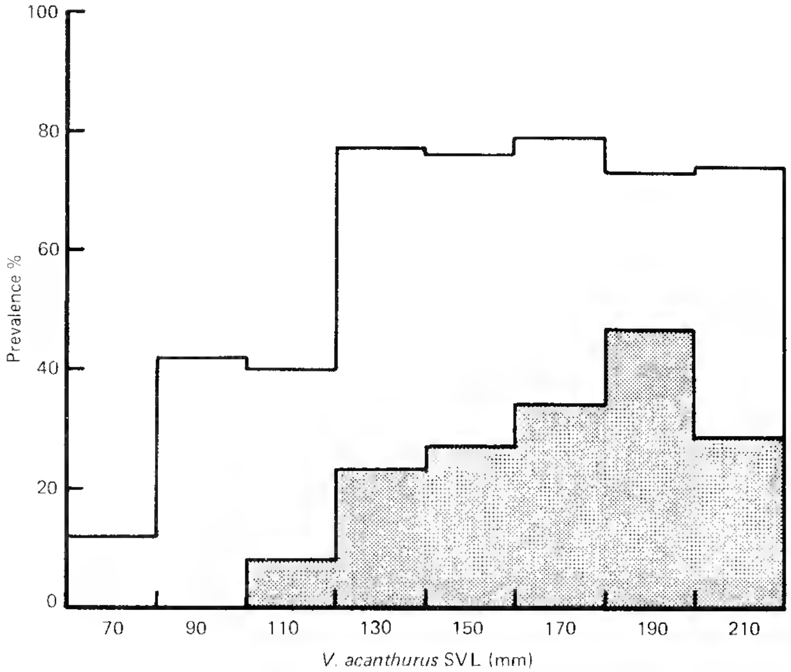

Figure 3a Prevalence of adult *A. hastaspicula* infection (open), and prevalence of infection with >20 adult *A. hastaspicula* (shaded) in relation to host size.

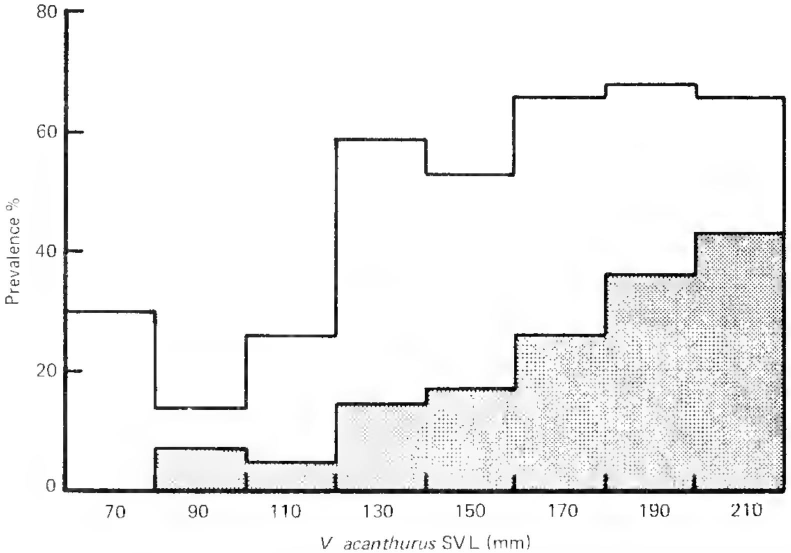

Figure 3b Prevalence of larval *Abbreviata* spp. infection (open) and prevalence of infection with >10 *Abbreviata* spp. larvae (shaded) in relation to host size.

Abbreviata confusa was only recorded from the northern part of the range of *V. acanthurus*, north of 18°S, where the mean annual precipitation is > 50 cm (Figure 1c). There was no clear seasonality in occurrence of infection (Figure 2c), although more data are needed to confirm this. Intensity of infection was unaffected by concurrent *A. hastaspicula* infection.

Fifty per cent of *V. acanthurus* contained *Abbreviata* spp. larvae in their stomachs. Prevalence of larval infection increased with host size to an SVL of approx. 170 mm, and then became constant. Prevalence of moderate intensity larval infections (>10 worms) increased throughout the size range of the host (Figure 3b).

Two hosts from the Prince Regent National Park in the Kimberley were infected with one male, and with two females and an immature, of a form very similar to *A. tumidocapitis* Jones, 1983. The females had a tubular vulva similar to that in *A. hastaspicula,* but in both specimens the eggs were infertile and distorted and could not be examined. Both infections were concurrent with *A. hastaspicula*.

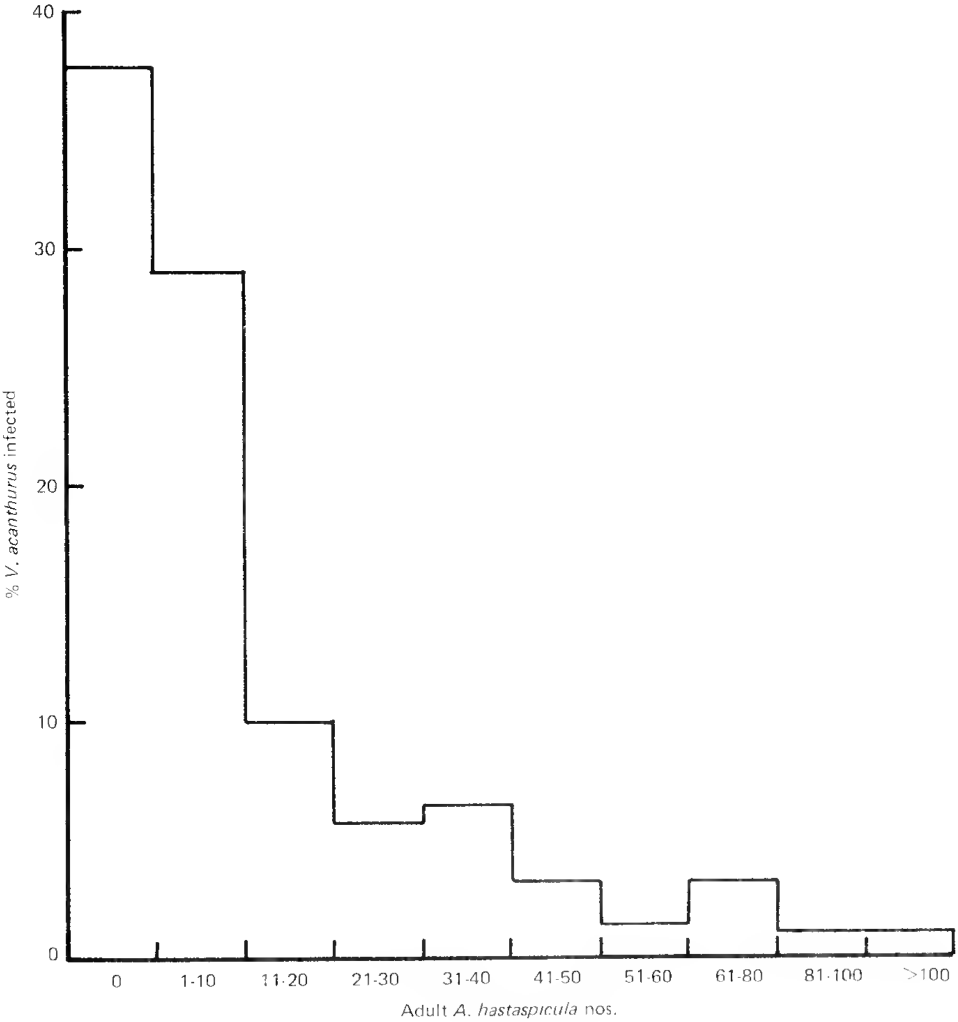

Figure 4 Prevalence and intensity of *A. hastaspicula* infection in *V. acanthurus*.

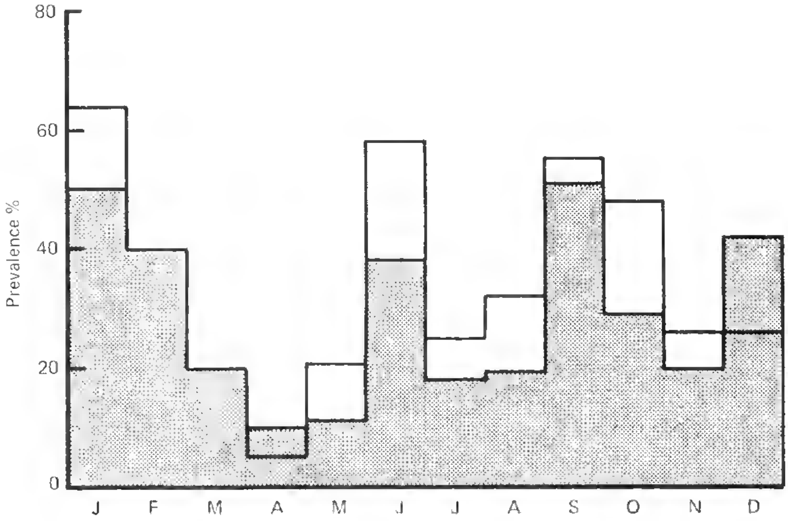

Figure 5 Seasonal prevalence of >20 adult *A. hastaspicula* (open) and >10 larval *Abbreviata* (shaded); single species infections only.

Discussion

This investigation demonstrates that *Abbreviata* spp. are the predominant gastric nematodes in *V. acanthurus* throughout the geographical range of the host. The three described species recorded in this monitor occur in other reptile species in Western Australia (Jones 1978, 1983) although their full geographical distribution and host specificity are not yet known.

Physalopterid nematodes require an arthropod intermediate host for the completion of their life cycles, but the invertebrate species involved, and other details of their life cycles, have not yet been studied in these species of *Abbreviata*. The geographical distribution of the species recorded in *V. acanthurus*, and the seasonality in occurrence of *A. antarctica*, probably reflect differences in their respective intermediate hosts, but may result from the differential survival of their eggs in the external environment. The diet of *V. acanthurus* specimens examined in this study consisted almost entirely of small lizards and invertebrates, two-thirds of the total food items comprising grasshoppers (44%), beetles (17%) and cockroaches (6%) (King, in press); there was no seasonality in occurrence of these insect groups. It is probably among the cockroaches and scavenging beetles that a search should be made for the intermediate hosts of these worms. The positive correlation between numbers of adult and larval *A. hastaspicula* is difficult to explain on the available data. The close similarity between adult and larval numbers throughout the year indicates that there is no seasonal maturation in this species.

Future studies are needed on the identity and distribution of intermediate hosts, on the longevity of the worms, and on possible immune mechanisms in the reptilian hosts in order to elucidate more of the biology of these species of *Abbreviata*.

Acknowledgements

I am grateful to Dr Dennis King for collecting and forwarding the worms recovered during the course of his own work, and to Ms J. Covacevich for allowing me to examine reptilian hosts from the Queensland Museum. Dr G.M. Storr and G. Gow also agreed that the worms from the lizards in their collections could be used for this study. Financial support was received from the ARGS.

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Lepidogalaxias salamandroides Mees — A Redescription, with Natural History Notes

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Abstract

Lepidogalaxias salamandroides Mees is redescribed, knowledge of its relationship reviewed, sexual dimorphism discussed, and specializations related to its habits and habitats reported. The eyes are adnate, lacking eye muscles and a curious ability to bend the head downwards and sideways is noted.

Introduction

The description in 1961 by Mees of a so-called 'scaled galaxiid', *Lepidogalaxias salamandroides*, revealed one of the most distinctive and enigmatic freshwater fish discovered in recent times. The fish itself is small and unspectacular. It reaches only about 70 mm, and is rather drab-coloured but is seemingly highly specialized. Although Mees (1961) included the species in the Galaxiidae, his view was (p. 33) 'that it seems impossible to place it in any of the extant genera of the Galaxiidae', suggesting it belongs 'perhaps even in a separate subfamily' (p. 38).

Superficial examination indicates that, apart from the dorsal fin being posteriorly placed, over the anal, there is little obvious cause to include the fish in the family Galaxiidae. More detailed study supports this view. McDowall (1969) in a review of Southern Hemisphere salmoniform freshwater families (Galaxiidae, Aplochitonidae, Retropinnidae, Prototroctidae) expressed the opinion that the 'odd little species *Lepidogalaxias salamandroides* is not a galaxiid'.

Frakenberg (1969: 108) concurred: '. . . *Lepidogalaxias* is clearly distinct not only from galaxiids but in certain respects from salmoniform fishes as a whole'. In Frankenberg's opinion (1968: 9; 1969: 108), the species belongs in a separate family Lepidogalaxiidae. Familial status was assigned by Rosen (1973: 483) without background comment, and reaffirmed by Rosen (1974: 311). Lake (1972) listed *Lepidogalaxias* in the Galaxiidae, as did Nelson (1976) who was aware of Rosen's view (1974), but Lake (1978) recognized Lepidogalaxiidae, as did Berra (1981) and Allen (1982).

The relationships of this fish are far from obvious. Frankenberg (1968) was the first to comment on these noting that *Lepidogalaxias* (p. 9) 'can in most respects be regarded as ancestral to the galaxiids . . . is at least as primitive as any living teleost, and among these, it serves to relate the galaxiids with the Northern Hemisphere esocoid fishes rather

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than with the salmonids.' Rosen (1974: 269) thought that 'A review of the anatomy of salmoniform gill arches, caudal skeleton, and secondary sexual characters suggests that *Lepidogalaxias* is an esocoid . . .' This view is somewhat astounding, because if correct, it means that *Lepidogalaxias* is the only representative of the sub-order Esocoidei in the Southern Hemisphere. Although acceptance of Rosen's view of the relationship is difficult no other plausible views have been offered. The implications for the evolution and biogeography of world freshwater fishes are profound, and yet the survival of a relict esocoid in south-western Australia really has no important biogeographical implications until a much clearer picture of relationships emerges.

Fink and Weitzman (1982) were dubious about the supposed esocoid relationship — 'Of the eleven characters Rosen (1974) used to place *Lepidogalaxias* in the Esocae, only four appear to be appropriate for inference of relationship . . . In view of the reductive nature of all of these characters and the very small size and benthic 'habits' of *Lepidogalaxias* and in view of the biogeographic hypothesis suggested by this hypothesis of relationships a further search for characters is warranted' (p. 81-82). *Lepidogalaxias* ranks, in Australia, with the dipnoan *Neoceratodus* as an ancient endemic whose occurrence in Australia 'is of interest primarily because of the survival of an ancient fish stock rather than for reasons of biogeography . . .' (McDowall 1981: 1257). Rosen (1974) believed that the esocoid relationship of *Lepidogalaxias* 'dates to the fragmentation of Pangaea'. Beyond this, (whatever the real relationships) little can be said about the zoogeography of this species; again its interest lies primarily in its survival (McDowall 1981: 1258).

Thus we have, in south-western Australia, this small fish, superficially unspectacular but highly specialized and belonging to an endemic monotypic family whose nearest relatives may be northern temperate esocoids, but which may also belong somewhere else amongst the most primitive of teleost fishes.

Since its initial, brief description, based on only 6 specimens 37-60 mm total length, little has been published. The only detailed observations are those of Rosen (1974) primarily on osteology and relationships, with some comment on sexual dimorphism in the structure of the anal fin.

The availability of additional material provides the opportunity for an expanded description and examination of sexual dimorphism. In addition observations on habitats occupied and better definition of the geographical area occupied become possible.

Study methods follow those of Hubbs and Lagler (1958), as outlined, and modified by McDowall and Frankenberg (1981).

Systematics

Genus *Lepidogalaxias* Mees, 1961

Type Species

Lepidogalaxias salamandroides Mees 1961: 33, by original designation.

Lepidogalaxias salamandroides Mees
Figure 1

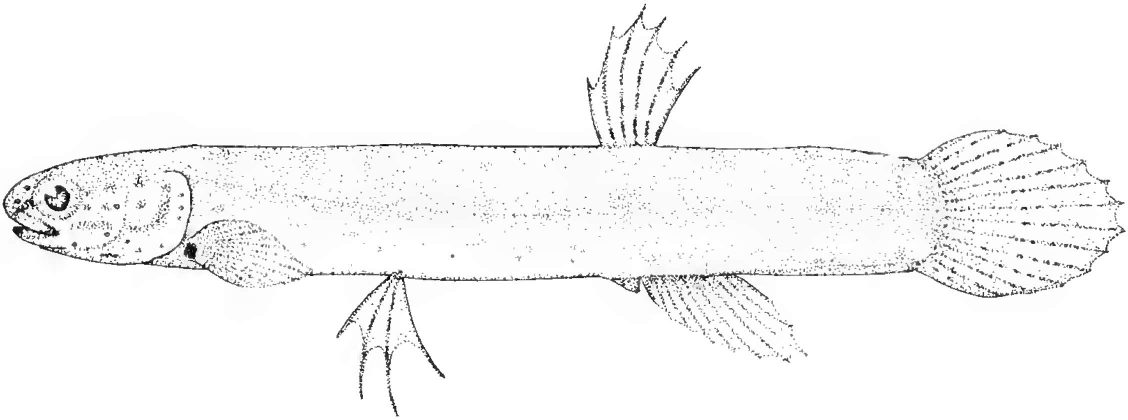

Figure 1 *Lepidogalaxias salamandroides* Mees; female, 70.5 mm TL Shannon River, W.A. (WAM P.27522-001).

Diagnosis

Characterized by elongate slender form; scales present, rudimentary, on lateral surfaces only; dorsal fin far back on trunk very short-based but high; abdominal pelvic fins with very long rays; orbits adnate; sexes different, male with enlarged anal fin sheathed with scales.

Description

Small, elongate and slender. Trunk tubular to slightly compressed, increasingly so towards tail, dorsal and ventral trunk profiles parallel from head to tail, tapering anteriorly to a blunt snout; caudal peduncle very long, deep, somewhat compressed, much longer than deep.

Head short, broad posteriorly but anteriorly is laterally compressed to form a narrow, beak-like snout, which is short and blunt. Mouth of moderate size, only slightly oblique, reaching back well below eyes, mouth terminal, jaws about equal. Eyes of moderate size, adnate, high on head, upper margin nearly level with upper head profile, interorbital flat, narrow. Nostrils simple apertures. Teeth in jaws uniserial, lacking enlarged canines, no teeth on tongue but a row of strong palatine-vomerine teeth in roof of mouth. (Mees 1961, calls the palatine teeth endopterygoidal). Gill rakers short and stout. Operculum free from isthmus, margin entire without spines.

Gut with a simple pouched stomach and a single intestinal loop, lacking pyloric caeca.

Scales present, cycloid, very thin, outer margin heavily invested in skin confined to lateral surfaces thus absent from back and belly, absent also from head, but present from opercular opening to tail base, about 65 in mid-lateral series; lateral line present, running along mid-lateral from opercular opening to tail base. Only laterosensory pores on head a row in preopercular series; rows of papillae as in Figure 2. All fins membranous; only one dorsal fin, positioned posteriorly on trunk above vent, very short-based but high, flag-like and pointed, third (middle) ray much the longest, none or few procurrent rays. Anal fin small, short-based and rounded, few procurrent rays, fin in male modified for reproductive purposes (see Sexual Dimorphism below). Pelvic fins mid-abdominal, central pair of rays very much elongated with outer half of these free, not connected by membrane; pectoral fins short and rounded, paddle-shaped. Tail long, rounded, tending to bluntly pointed, central rays much the longest, procurrent rays weakly developed, caudal peduncle flanges strongly developed.

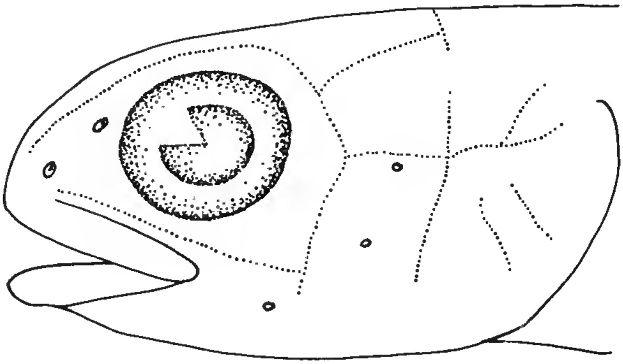

Figure 2 Disposition of laterosensory pores and papillae on head of *Lepidogalaxias.*

Colour of female: When alive brown to greenish-brown, with a series of brown-black saddle-like markings along back, a mid-lateral series of dark blotches, tending to form a pair of irregular longitudinal lines along the trunk, the lower of these establishing the ventral margins of pigmentation on the trunk, below this the belly silvery-white, sometimes with a soft rosy flush.

Head colour similar to trunk, brownish with black markings, a distinct dark line across upper operculum, through eye and across snout to upper lip, a second line across mid-lower operculum and cheeks below eye to corner of mouth, below this, the head silvery white.

Fin membranes unpigmented, but fin rays with strong, irregular dark brown-black markings.

Males are distinctly darker, the lateral blotching evident in the females becoming consolidated to form a definite mid-lateral dark brown to black band.

In preservative grey-black, with paler grey areas, and belly white, marking patterns as in life.

Sexual dimorphism: sexes distinct although not markedly so. The pelvic fins in the male are much longer than those in the female (Table 1) and females grow much larger than males (Figure 3), but the chief difference is in the structure of the anal fin. This is, in part, evident from the data in Table 1, where figures show that the length of the anal fin base of the male is almost twice that of the female. The male anal fin is extensively modified, being sheathed with a series of greatly enlarged scales that originate adjacent to the anal fin base, and project ventrally to encase the proximal two-thirds of the fin, the distal third

Table 1 Morphometric variation in *Lepidogalaxias salamandroides* (figures given as % of denominations in ratios).

	Male				Female			
	Min.	**Mean**	**Max.**	**SD**	**Min.**	**Mean**	**Max.**	**SD**
Total length/standard length	115.3	120.65	125.0	2.95	113.9	119.71	124.1	3.42
Body depth at vent/standard length	13.2	15.24	17.7	1.42	11.6	12.75	13.9	0.78
Length of caudal peduncle/standard length	20.0	22.48	24.2	1.35	21.2	24.06	27.8	1.94
Depth of caudal peduncle/standard length	11.0	12.86	15.1	1.55	10.5	12.87	14.6	1.22
Depth of caudal peduncle/length of peduncle	50.0	57.01	65.5	5.73	46.1	54.24	63.6	4.52
Predorsal length/standard length	62.1	64.83	67.6	1.87	63.0	65.23	68.8	2.01
Preanal length/standard length	64.4	67.36	69.7	1.88	67.9	70.65	73.8	1.69
Predorsal length/preanal length	91.9	96.19	98.8	2.13	88.0	92.14	94.6	2.40
Length of dorsal fin base/standard length	4.2	4.91	7.3	0.74	4.0	5.50	6.8	0.91
Maximum length of dorsal fin/basal length	300.0	376.33	440.0	45.94	264.7	324.36	375.0	39.72
Length of anal fin base/standard length	11.8	13.54	17.7	1.04	6.3	7.44	8.1	0.65
Maximum length of anal fin/basal length	131.6	142.24	162.5	13.31	185.7	195.36	200.0	6.56
Pectoral fin length/pectoral pelvic length	52.9	60.81	69.2	5.15	49.0	57.32	63.0	4.71
Pelvic fin length/pelvic anal length	100.0	123.08	135.7	10.45	76.9	84.63	94.7	5.93
Prepelvic length/standard length	42.4	44.92	48.5	1.79	41.0	43.23	44.6	0.99
Pectoral pelvic length/standard length	20.0	23.31	25.0	1.50	20.7	22.53	25.0	1.30
Pelvic-anal length/standard length	21.9	23.26	25.8	1.10	25.7	27.96	30.5	1.53
Head length/standard length	17.7	21.24	24.2	2.06	20.1	22.11	24.1	1.20
Head width/head length	50.0	56.05	60.9	3.70	51.1	56.83	63.2	4.80
Head depth/head length	50.0	56.39	60.9	3.64	50.1	54.17	59.4	3.42
Snout length/head length	16.7	18.38	21.7	1.67	17.1	19.86	22.2	1.94
Postorbital head length/head length	56.0	62.40	69.6	5.28	57.1	61.63	65.2	2.59
Interorbital width/head length	13.3	15.46	20.0	2.37	13.2	16.75	20.5	2.36
Eye diameter/head length	23.1	26.32	32.1	2.34	19.6	22.42	25.0	1.70
Length of upper jaw/head length	28.0	34.68	39.1	3.43	31.1	34.76	37.5	2.18
Length of lower jaw/head length	28.0	25.47	34.8	2.07	29.7	33.10	36.8	2.02
Width of gape/head length	30.0	34.82	39.1	3.48	28.6	33.37	36.8	2.38
No. measured	10				10			

projecting back between the sheathing scales (Figure 4). Rosen (1974) has described extensive modification of the fin skeleton in this fin (Figure 5). He (p. 301) reported that the anal fin of 'the fully differentiated male always occurs strongly folded to the right or left in preserved specimens', and that 'Histological study of the entire anal fin region in *Lepidogalaxias* shows that the sperm duct opens into a sinus near the anal fin origin . . . bounded partly by the scale sheath and . . . continuous with a channel formed by the ventral edge of the scale sheath and the folded anal fin rays. This channel opens to the outside near the tip of the posterior rays of the fin two of which are bifurcated. Presumably the channel conveys sperm . . .'

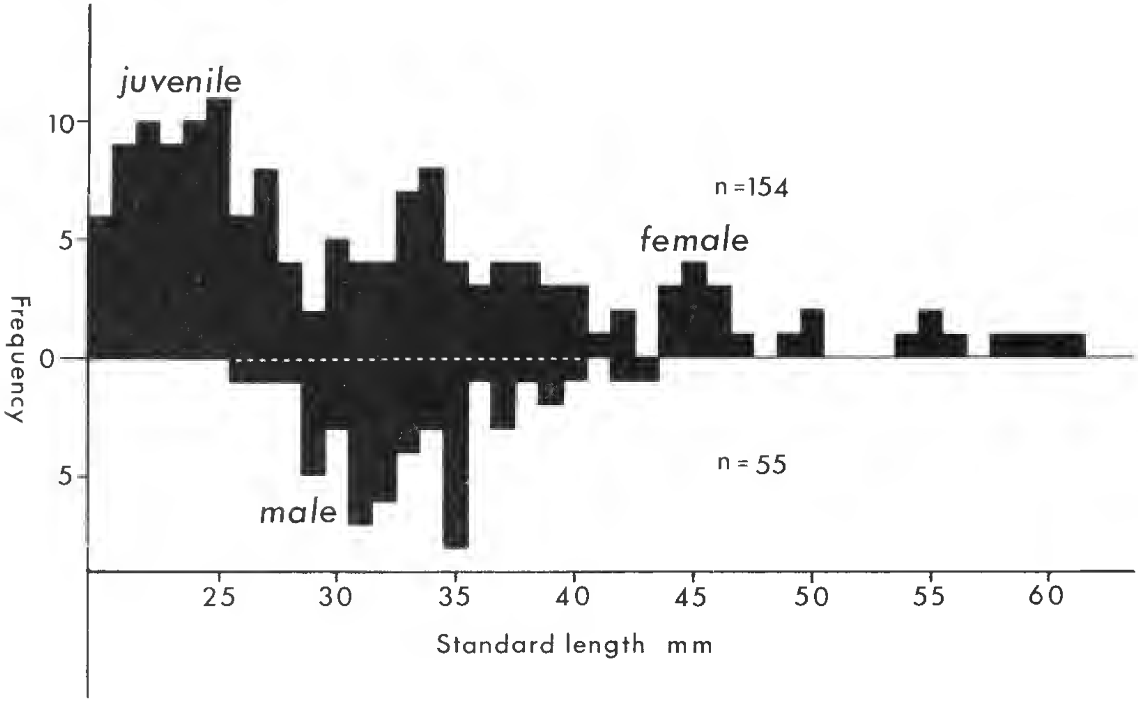

Figure 3 Size-frequency distribution of male and female *Lepidogalaxias salamandroides.*

So little is known about the natural history of this species that the significance of this structure in the male, and how it functions, remain obscure.

The female, in contrast, has a form of genital papilla that protrudes from the abdomen, adjacent to the vent and just in front of the unmodified anal fin.

Size: *Lepidogalaxias salamandroides* is known to reach 61.0 mm S.L. (70.5 mm T.L.), this being a large female from the Shannon River, 10 January 1982 (WAM P.27522-001). Allen (1982) reports it as 'Maximum size to about 5 cm SL, commonly to 3.5 cm SL', and this is in accord with the data we have (Figure 3). Males are smaller than females, the largest male measured in this study being 43 mm SL, most being 30-35 mm SL. Females were commonly about the same size, but much larger females were also present in the populations.

Figure 4 Anal fin of mature male *Lepidogalaxias salamandroides*.

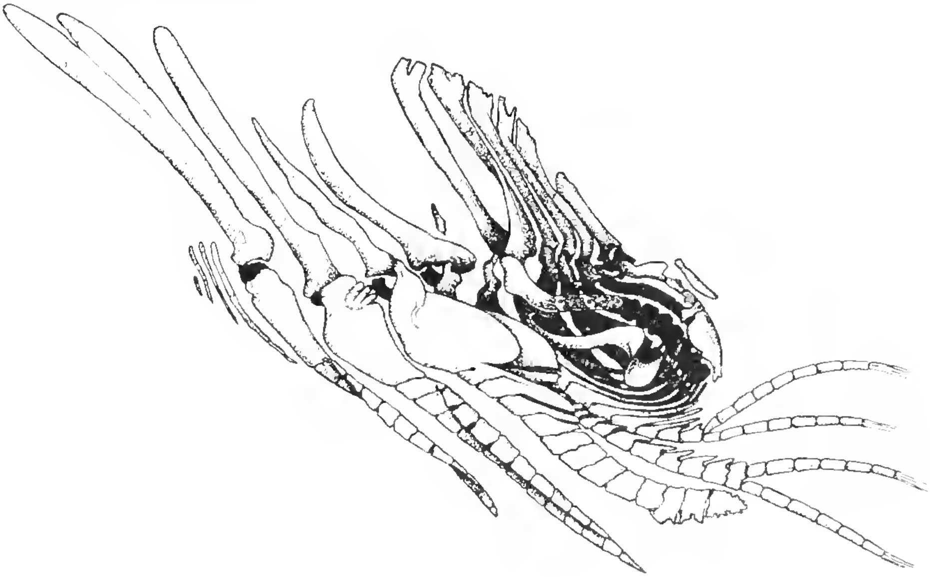

Figure 5 Structure of support of anal fin in male *Lepidogalaxias salamandroides* (from Rosen 1974).

Table 2 Meristic variation in *Lepidogalaxias salamandroides*

		Male		Female
Dorsal rays	0-5	1		1
	0-6	5		2
	0-7	-		1
	i-5	1		-
	i-6	3		1
	i-7	-		1
	ii-6	-		4
Anal rays	ii-11	-*		5
	ii-12	-		-
	iii-11	-		3
	iii-12	-		2
Caudal rays	12	8		7
	13	1		3
	14	1		
Pelvic rays	4	10		10
Pectoral rays	10	1		
	11	6		5
	12	3		5
Gill rakers	4			1
	5	3		3
	6	2		6
	7	1		
Vertebrae†	43		1	
	44		4	
	45		6	
	46		6	

* Not counted owing to highly modified character of anal fin in males.

† Includes all vertebrae with articular facets at both ends, a 'total count' is one greater.

Distribution and Habitat

L. salamandroides is found most commonly in shallow streams and pools of the southern acid peaty flats of southern Western Australia (Figure 6). It is rarely found in streams of the karri forest although these are listed as the type location. These flats are typified by acid, brown streams and a characteristic floral composition, the principal species being stunted *Eucalyptus marginata, Nuytsia floribunda, Casuarina humilus, Zanthorrhea preisii, Melaleuca, Beaufortia* and a *Banksia* spp. Allen (1982: 19) reported that the fish 'are generally associated with acidic water ranging in pH from about 4.5 to neutral'. There is no aquatic vegetation. Its range is an area of high rainfall, in excess of 1200 mm, and mild temperatures — summer maxima of 25-30°C and winter minima of 5-10°C. Rainfall is highly seasonal with the peak during winter and least during summer.

Figure 6 Distribution of *Lepidogalaxias* in Western Australia.

Natural History

The natural history of *L. salamandroides* is not well known. Since first described more than 20 years ago little has been reported although one of us (B.J.P.) has examined aspects that will be published elsewhere.

When first collected by Mees (1961) the fish were taken from a creek that was 'probably permanent, the water cool and fairly rapidly flowing . . . the creek bed was largely filled with *Eucalyptus* leaves especially in those places where the creek was slightly wider and deeper. It was by taking out this layer of leaves mixed with some mud, and carefully going through it that we obtained our specimens.' Allen (1982) stated 'this species is apparently capable of surviving drought periods by burrowing in mud or under damp leaves. Studies

(B.J.P.) show that the fish may burrow either head or tail first and construct a loose-pear-shaped burrow connected to the surface by a thin tube. They assume a U-shaped posture in the burrow (Figure 7).

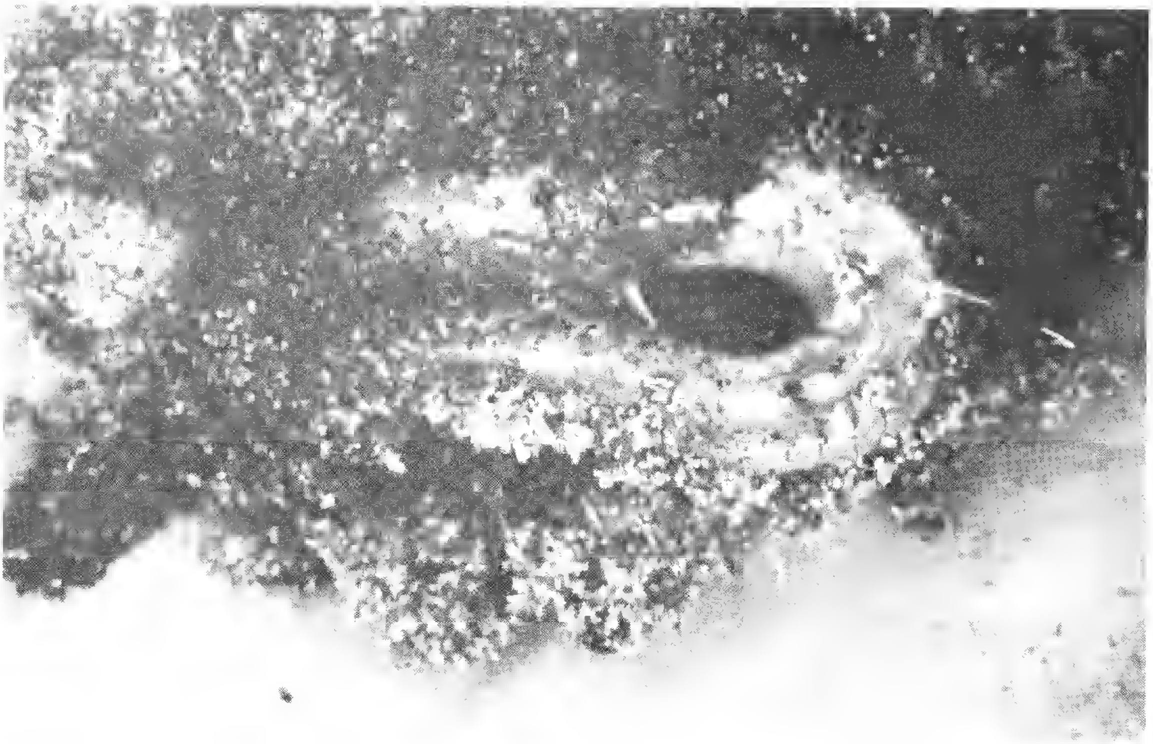

Figure 7 *Lepidogalaxias salamandroides* as found aestivating.

Spawning occurs in the spring. Mees (1961) reported on a mature female caught in October with large eggs. Since this is approaching the dry season (summer) it might be hypothesized that the eggs are capable of surviving drought, and hatch when water returns in the autumn.

Population samples taken during the late autumn-early spring of 1981 reveal the juveniles from the spawning of the previous spring, plus a few adults, in the population in April. These juveniles move into the adult population as they mature during the winter. The males mature during their first year while the females delay maturity until the second.

The eyes are adnate, lacking a circum-orbital sulcus (Figure 8) and are covered by a secondary eyelid. This structure is presumably an adaptation to protect the eyes when burrowing in benthic detritis and when aestivating during periods of drought. Observations on behaviour in captivity reveal the ability of the fish to bend the 'neck' at a quite sharp angle either sideways and/or downwards (Figure 9). This behaviour is related to food search, the fish observing moving food items on the tank bottom, moving adjacent to them, and bending the head sideways and/or down to locate the items before engulfing them.

Frankenberg (1969: 116) refers to 'spaces between the anteriormost vertebrae' and these are evident in cleared and stained specimens between the exoccipital, the first and second vertebrae. Possibly the spacing of the vertebrae increases the flexibility of the anterior vertebral column, facilitating the bending of the head sideways or downwards referred to above.

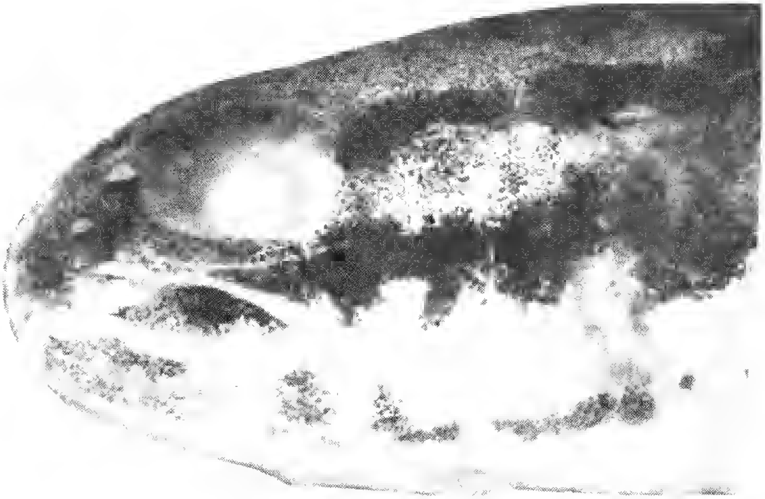

Figure 8 Eye of *Lepidogalaxias salamandroides* (note absence of circum-orbital sulcus).

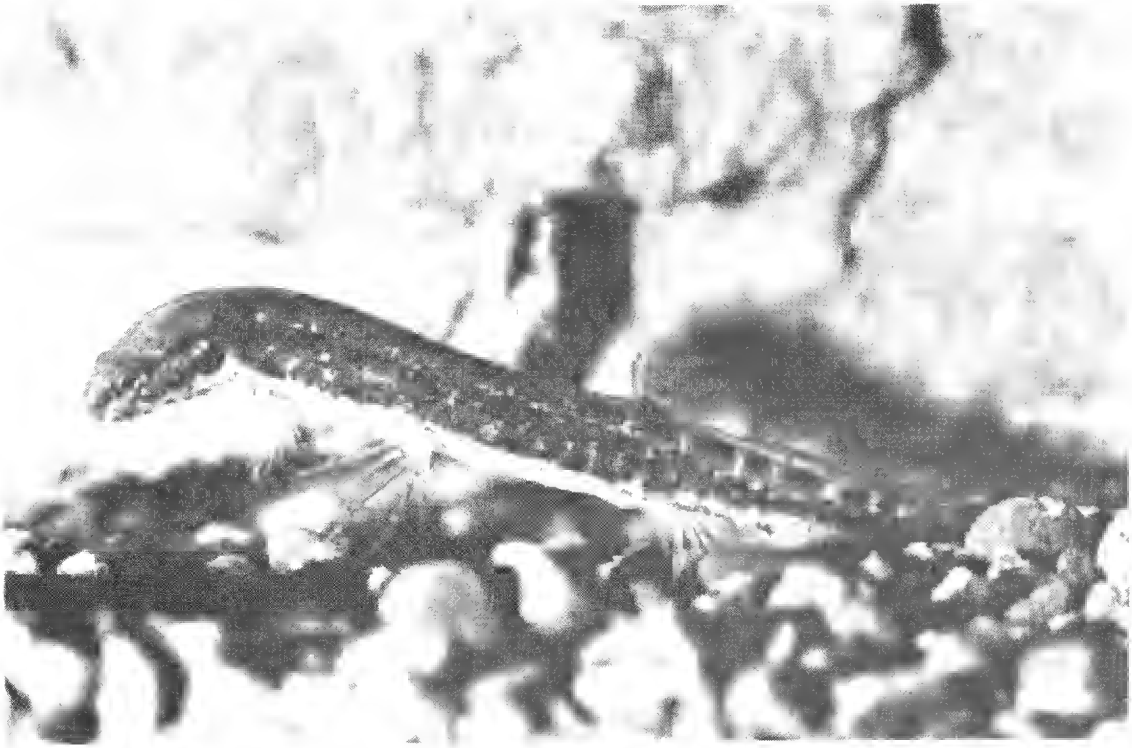

Figure 9 *Lepidogalaxias salamandroides* female (note elevated trunk perched on pelvic fins and distinct bend of neck).

Dissections of the eye failed to reveal the presence of the eye muscles that control eye movements in typical fish, and during observations of both mobile and anaesthetized live fish, no eye movements were noticed. The apparent inability of the eye to move is predictable inasmuch as the presence of the folded epidermis in the circum-ocular sulcus of typical fishes, but lacking in *Lepidogalaxias,* is what allows the eye to rotate in its socket.

Another interesting behaviour is the posture commonly adopted by the fish. The pelvic fins, which have greatly elongated central rays that are unconnected distally by membrane, are capable of rotating forwards so that the central rays point forward. *Lepidogalaxias* in captivity were commonly observed to raise the entire trunk up from the substrate resting on a tripod formed by the tail and the forward-rotated and outspread pelvic fins so that head was elevated at an angle of 30° or more and the pectoral fins hanging in space free from the substrate. This posture was commonly adopted during the search phase in feeding in captivity (Figure 9).

Much remains to be learned of the relationships and natural history of *Lepidogalaxias.* Apart from the fact that it belongs amongst the most primitive of protacanthopterygian fishes its relationships seem poorly defined. Ecologically, little is known. In spite of its small size and unspectacular appearance this is a species of importance to Australian natural history; attention should be given to increased knowledge and to ensuring that its habitats and populations are protected.

Material Examined

WAM P.4887 holotype female, 49 mm SL (60 mm TL): Tiny creek about 6 miles ENE of Shannon River, 34°48′E, 116°26′S; WAM P. 4888, 3 paratypes, collected with holotype; WAM P.13922-23: Drains, Mt Chudalup Road, Windy Harbour, W.A. 1 October 1962; WAM P.7449-50: Shannon River, upstream from type locality, W.A. 30 May 1964; WAM P.7447: North Road, Shannon River (type locality), W.A. 31 May 1964; WAM P.27691-001: Creeks and waterholes, W.A. 34°50′S, 116°50′E, 3 October 1975; WAM P.27522-001: Pool Shannon River, 12 km east on Preston Road, Northcliffe, W.A. 34°38′S, 116°21′E, 10 January 1982; AMS I.17127-001: Under bridge of Y Plain, 22 miles west of Walpole, W.A., 34°55′S, 116°33′E, March, 1973; AMS I.19614-001: Pools on Windy Harbour Road, d'Entrecasteaux Pt, W.A. 34°50′S, 116°00′E, 22 October 1976; AMNH 37674; 12.3 miles south of Northcliffe on Windy Harbour Road, W.A. 9 March, 1969; FRD Unregistered: 3 km north of Mt Chudalup, Windy Harbour 116°08′E, 34°28′S, on Windy Harbour Road; FRD Unregistered: 5 km west of Shannon River on Chesapeake Road, 116°28′E, 34°22′S.

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A Review of the Mangrove Kingfisher, *Halcyon chloris* (Boddaert) in Australia, with a Description of a New Subspecies from Western Australia

R. E. Johnstone*

Abstract

Two subspecies of the Mangrove Kingfisher are recognized for Australia, namely *Halcyon chloris sordida* from Kimberley (Western Australia), Northern Territory, Queensland and northern New South Wales, and *Halcyon chloris pilbara* subsp. nov. from the Pilbara, Western Australia. The new subspecies differs from *sordida* in its smaller size and duller coloration.

Introduction

The Mangrove Kingfisher *(Halcyon chloris)* is widely distributed. It extends from the Red Sea through eastern Arabia, southern Asia, the Philippines, Indonesia, Papua New Guinea, northern Australia, to Polynesia (as far as Samoa). Thc species undergoes much geographic variation and at present forty-seven subspecies are recognized (Peters 1960). In Australia it inhabits northern coastal mangroves, extending south to the Tweed River (northern New South Wales) on the east coast and to Exmouth Gulf on the west coast (perhaps further south in the past).

The abundant and smaller Sacred Kingfisher *(Halcyon sancta)* has often been mistaken for the Mangrove Kingfisher; hence the erroneous distribution given for the latter in many texts. Prior to 1980 there were only three acceptable records of the Mangrove Kingfisher from the Kimberley Division (Western Australia) and six from the Pilbara.

In October 1980 a detailed study of seventeen large blocks of mangal in the Pilbara region was carried out by the Department of Ornithology and Herpetology of the Western Australian Museum. Mangrove Kingfishers were observed in nine separate localities and thirteen specimens were collected. In October 1982, eight specimens were collected during a survey of the mangroves of Cambridge Gulf (north-east Kimberley) by the Department of Fisheries and Wildlife and the Western Australian Museum. These series have allowed a better understanding of geographic variation in Western Australia.

Of six specimens taken by early collectors from the Pilbara, three were from Point Cloates by T. Carter (one on 2 May 1889, one on 14 June 1900 and one on 1 May 1901). Although labelled Point Cloates, Carter used this locality in a broad sense, and there is little doubt that these specimens came from further north at Yardie Creek or perhaps Mangrove Bay.

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There has never been suitable habitat for this kingfisher at Point Cloates, and the mangal at both Yardie Creek and Mangrove Bay is now inadequate. A Mangrove Kingfisher was collected at Cossack by F.L. Whitlock on 17 October 1917. Whitlock did not identify his specimen as a Mangrove Kingfisher, and it is obvious from the literature that both he and Carter confused Mangrove and Sacred Kingfishers. However, the identity of these specimens is not in doubt as J.R. Ford (pers. comm.) has checked the two specimens collected by Carter in May, and A.R. McEvey (McKenzie 1979) has checked Carter's June specimen and Whitlock's specimen. Two immature Mangrove Kingfishers were collected by P. Montague on Hermite Island in the Monte Bello Islands in 1912. In 1955 the atomic blast destroyed the habitat there.

Materials and Methods

Sixty-two Australian specimens of the Mangrove Kingfisher held in the Western Australian Museum, Australian Museum, National Museum of Victoria, South Australian Museum, Queensland Museum, Australian National Wildlife Collection and Arid Zone Research Institute (Northern Territory) were examined. Measurements were taken as follows: length of chord of flattened wing, length of tail (along a central rectrix), length of tarsus, length of entire bill and maximum depth of bill.

Australian Subspecies

Halcyon chloris sordida Gould

Description

Adult male: Head and nape dark greenish-olive except for a hidden or partly hidden white spot on nape; loral spot white; a broad white collar (see Figure 1) separated from head by narrow black band; back and scapulars olive-green, becoming tinged with blue on wing coverts; outer web of flight feathers blue or greenish-blue; rump and tail coverts light bluish-green; tail greenish-blue; underparts white (some specimens with faint brownish-black barring on flanks, breast and sides of throat). Iris dark brown; bill black except for base of lower mandible, which is whitish; mouth pink; legs pale brown or blue-grey.

Adult female: Differing from male in having head dark greenish-brown; back and scapulars greenish-brown; outer web of flight feathers greenish-blue; rump and tail coverts olive-green; tail light greenish-blue.

As the name implies, *sordida* is one of the dullest forms of the Mangrove Kingfisher. *Halcyon chloris chloris* is much more bluish on the head, back, wings and tail.

Distribution

Northern New South Wales, Queensland, Northern Territory and Kimberley Division of Western Australia (see Figure 2), also southern New Guinea.

Status

In New South Wales Morris, McGill and Holmes (1981) give the status as rare, possibly resident, recorded from August to February. It is seen regularly at the lower Tweed River.

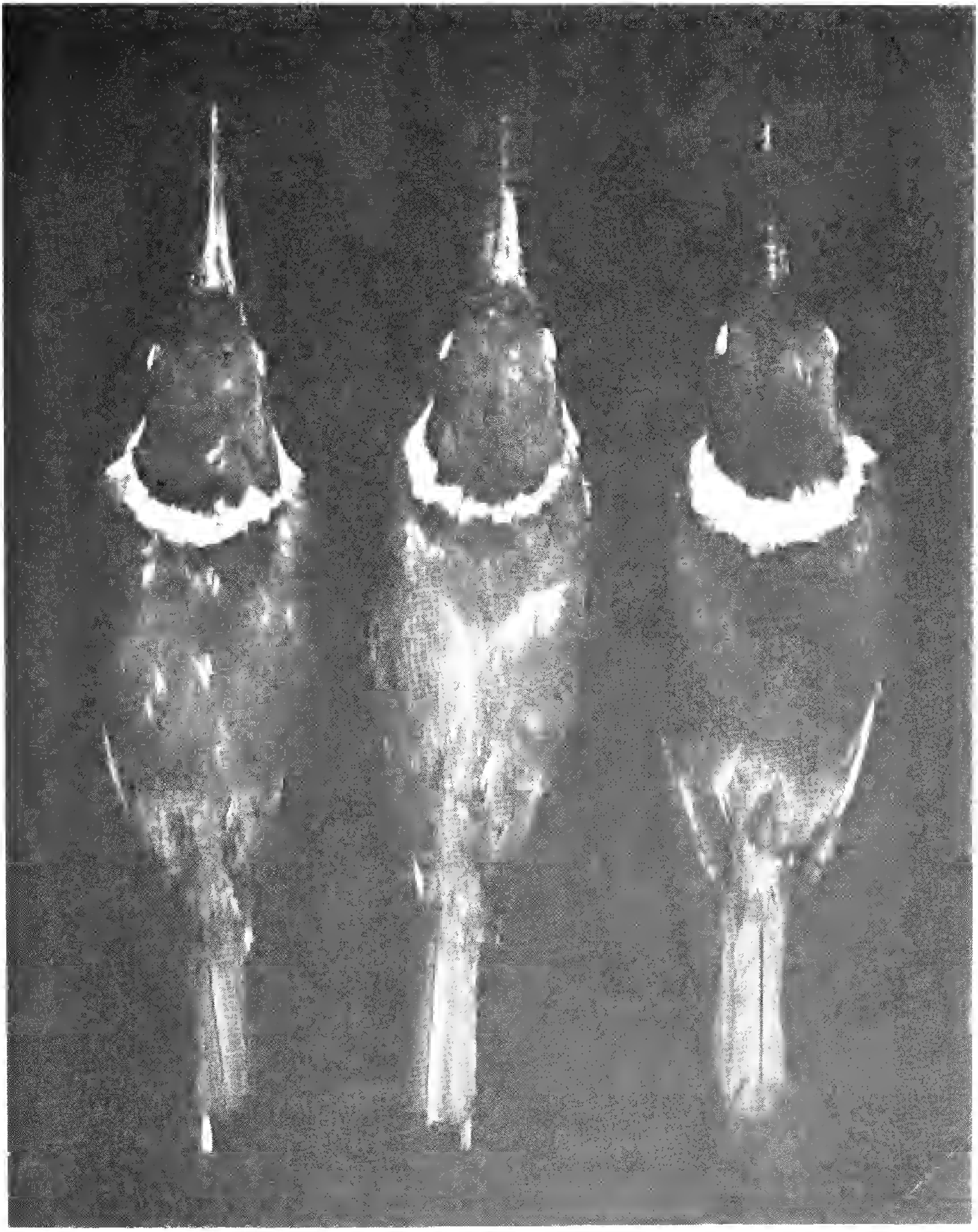

Figure 1 Dorsal coloration of (left to right): male *Halcyon chloris pilbara* (A16690), female *H. c. pilbara* (A16686) and male *H. c. sordida* (A12621). Photographed by C. Bryce.

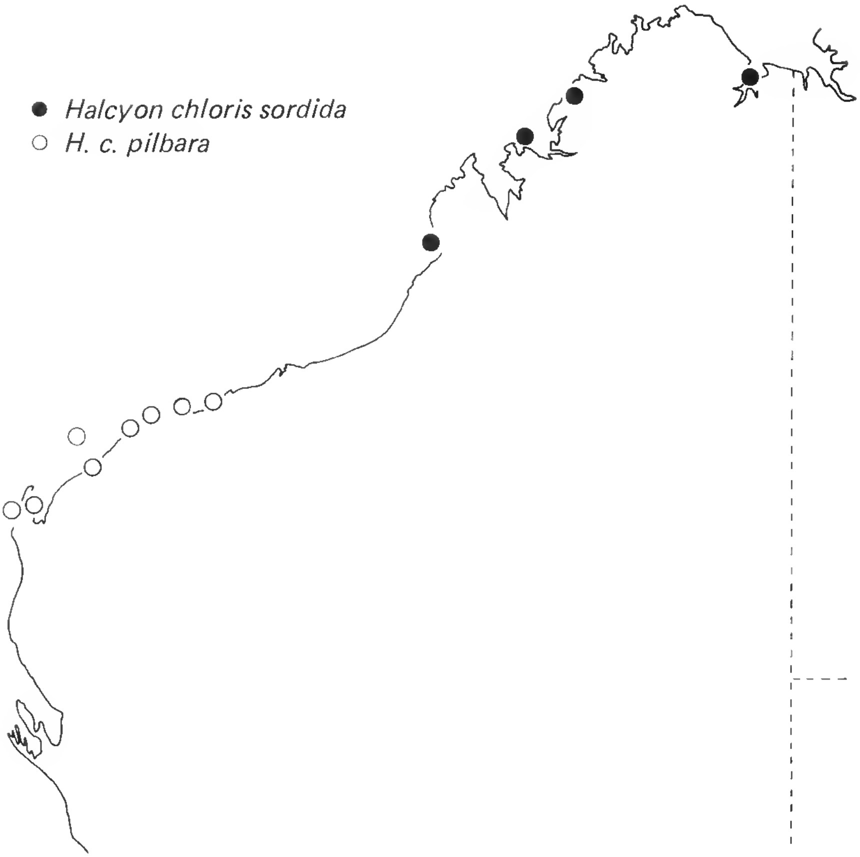

Figure 2 Map of northern Western Australia, showing the distribution of *Halcyon chloris sordida* (solid circles and *H. c. pilbara* (hollow circles).

In Queensland Storr (in press) lists it as locally common but generally uncommon and patchily distributed. In the Northern Territory Storr (1977) gives the status as moderately common, and in the Kimberley Storr (1980) recorded it as very rare. Recent work in Cambridge Gulf (north-east Kimberley) has shown that the Mangrove Kingfisher is common in this area in *Rhizophora* forest, and mixed *Rhizophora-Sonneratia* forest and woodland.

Halcyon chloris pilbara subsp. nov.

Holotype

Adult female (WAM A16686), collected by R.E. Johnstone and L.A. Smith on 6 October 1980 at mouth of Popes Nose Creek 2 km SW of Point Samson, Western Australia.

Diagnosis

Differs from *Halcyon chloris sordida* in its smaller size (Table 1); narrower bill (Table 1); duller paler and more brownish head and back and narrower white collar (only one of sixteen specimens having a collar wider than 7 mm). See Figure 1.

Table 1 Measurements (mm) of *Halcyon chloris* with sample size and means in parentheses.

		Wing	Bill length	Bill depth	Tail	Tarsus	Total length	Weight	$\frac{\text{Bill}}{\text{Wing}}$ %
Pilbara W.A.	♂ (N10)	93-104 (98)	55.5-61.0 (58.1)	10.7-12.0 (11.4)	65-71 (67)	15-18 (15.5)	241-257 (249)	50-67 (59)	59.2
	♀ (N10)	91-103 (97)	54.0-60.5 (57.2)	11.0-12.0 (11.3)	65-71 (69)	15-17 (16.0)	225-256 (246)	54-70 (63)	58.9
West Kimberley W.A.	(N 4)	105-107 (106)	57.0-66.5 (61.6)	13.6-13.7 (13.6)	71-76 (73)	15-17 (16.0)	260, 268	70-87 (76)	58.1
Cambridge Gulf W.A.	(N 8)	100-105 (102)	55.0-58.5 (56.9)	11.7-13.3 (12.1)	66-74 (70)	15-17 (16.0)	250-270 (260)	61-92 (71)	55.7
Northern Territory	(N16)	98-106 (101)	54.0-62.0 (57.2)	12.5-14.0 (13.0)	64-72 (68)	14-19 (15.5)		57-90 (69)	56.6
Queensland	(N15)	97-114 (105)	49.0-59.0 (54.6)		63-70 (67)	14-19 (17.0)	242, 260, 266	62, 92	52.0
New Guinea	(N 2)	99, 109	55.0, 53.5	11.6	62, 70	15, 16	242	85	52.1
All *sordida*	(N45)	97-114 (103)	49.0-66.5 (56.7)	11.6-14.0 (12.7)	62-76 (69)	14-19 (16.0)	229-270 (256)	61-92 (71)	55.0

Description

Adult male: Head brown (some specimens tinged with olive); white loral spot small to large, extending back in two specimens (a male and a female) as an ill-defined superciliary stripe; narrow white collar (Figure 1) separated from crown by narrow band of blackish-brown; back, scapulars and wing coverts pale olive-brown; outer web of flight feathers greenish-blue to bluish-green; rump and tail coverts olive-green; tail light greenish-blue; underparts white. Iris dark brown; bill black except for base of lower mandible, which is whitish; mouth pink; legs light grey to grey.

Adult female: Differing from male in having head brown; back, scapulars, wing coverts and rump dull olive-brown; outer web of flight feathers and tail dull greenish-blue.

Width of white collar 2-11 mm (mean 4.6 mm) *pilbara*, compared to 9-13 mm (mean 10.9 mm) in Kimberley *sordida*.

Distribution

Coastal Pilbara, Western Australia, from the mouth of the Turner River south to Exmouth Gulf (see Figure 2). Separated from *H. c. sordida* by the Eighty Mile Beach, which is almost devoid of mangroves.

Status

Moderately common to common. Confined to blocks of mangal with *Avicennia marina* forest or woodland. *Avicennia marina* is the only mangrove in this region large enough to produce nesting hollows not inundated by tides. When feeding they will often move into other mangrove habitats, including *Rhizophora* forest and woodland and mixed *Rhizophora-Avicennia* forest and woodland.

Voice

High-pitched 'ek ek' or 'kick it' rising in pitch on the second syllable. Churring 'keer' calls are also made.

Breeding

Most specimens collected in October 1980 and October 1982 had enlarged gonads. On 12 October 1980 a nest was found 38 cm down a hollow log wedged across branches of *Avicennia marina* at the mouth of the Cane River. The hollow was 10 cm wide, and the entrance was 2 m above the ground. A male bird was flushed from the nest and returned within a few minutes. The nest contained three pure white, slightly glossy eggs; they measured 32.0 x 25.3 mm, 30.9 x 24.9 mm and 30.5 x 25.6 mm.

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Redescription of the Clingfish *Cochleoceps spatula* (Gobiesocidae) from Western Australia and South Australia, with the Description of a New Species from Victoria and Tasmania

J.B. Hutchins*

Abstract

Cochleoceps spatula (Günther) is recognized as the valid name for a clingfish inhabiting Western Australia and South Australian seas. It can be distinguished from all other temperate Australian gobiesocids by its relatively long, depressed, rectangular-shaped snout and the anterior placement of its posterior nostril (anterior to front border of eye). The species is redescribed on the basis of new material from both States, as well as the holotype. Victorian and Tasmanian specimens previously identified as *C. spatula* represent a new species, *C. bassensis*. It may be separated from the former species by the more triangular-shaped snout and more posteriorly placed rear nostril (behind eye's anterior border). A description of this species is also included.

Introduction

Members of the clingfish family Gobiesocidae are generally small fishes possessing a ventral sucking disc that allows them to adhere to the substrate. Most occur in shallow coastal waters, often intertidally, but some have been found at depths over 250 m. Briggs (1955) recognized five species from temperate Australian seas in his monograph on the family. The number was increased to nine with the inclusion of the Cheilobranchidae with the Gobiesocidae by Springer and Fraser (1976). During the past decade, extensive collecting in the shallow waters along Australia's southern coastline has resulted in the discovery of many additional species (e.g. Hutchins 1977, listed 10 globiesocids for south-western Australia, of which seven were considered to be undescribed). The present total stands at 26 species which includes at least 16 species and four genera which are apparently new (Hutchins, in preparation). Dr J. Briggs of the University of South Florida is currently studying a number of these new genera and species. While attempting to identify a species from Western Australia characterised by an elongate body and long, rectangular-shaped snout, the present author noticed that it agreed well with the type description of *Cochleoceps spatula* (Günther, 1861) from Western Australia. However, it did not fit the subsequent description of this species appearing in Briggs' monograph. He diagnosed it as a robust clingfish with a broad, somewhat triangular-shaped snout, the description being based on specimens form Victoria and Tasmania. In order to resolve this confusion, the type of *C. spatula* was borrowed from the British Museum (Natural History) and compared with

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the Western Australian material. It was also contrasted with Victorian and Tasmanian specimens previously identified as *C. spatula*. This examination revealed that Günther's type and the Western Australian specimens are conspecific, while the Victorian and Tasmanian material represents a closely related, but nevertheless distinct species. Thus the purpose of this paper is to redescribe *C. spatula*, and to describe the new species from Victoria and Tasmania previously confused with it.

Methods

Measurements and counts follow Briggs (1955) with the following exceptions: the anteriormost point of the caudal peduncle's measurement of length was taken from the posterior termination of the anal fin integument; the minute uppermost pectoral fin ray is not included in fin ray counts; and the body width measurement was made at the level of the pectoral fin base. The head pore terminology generally follows that of Springer and Fraser (1976).

The material examined is deposited at the Australian Museum, Sydney (AM); British Museum (Natural History), London (BMNH); National Museum of Victoria, Melbourne (NMV); Queen Victoria Museum, Launceston, Tasmania (QVM); South Australian Museum, Adelaide (SAM); and the Western Australian Museum, Perth (WAM).

Systematics

***Cochleoceps spatula* Günther, 1861**

Figures 1, 2, 3a, 4a; Tables 1, 2

Crepidogaster spatula Günther, 1861: 508 (Type locality 'Gages Road' *[sic]* mouth of the Swan River, Western Australia).

Aspasmogaster spatula — McCulloch, 1929: 359 (part); Scott (E.O.G.), 1936: 119 (part).

Cochleoceps spatula — Whitley, 1943: 141 (part); Whitley, 1948: 28.

Diagnosis

This species is distinguished from all other known temperate Australian clingfishes on the basis of its relatively long, depressed, rectangular-shaped snout (dorsal view). In addition, both the anterior and posterior nostrils are located well in advance of the eye, whereas in all other temperate species at least the posterior nostril is either wholly or partly behind the eye's anterior margin.

Description

Measurements and counts of the holotype and selected non-type specimens are presented in Table 1. The following counts and proportions in parentheses represent the ranges for the non-type material where they differ from those of the holotype.

Dorsal fin rays 6 (4-7); anal fin rays 8 (6-8); pectoral fin rays 20 (17-20); pelvic fin rays I,4; caudal fin rays 10 (10-11); vertebrae 34-35; branchiostegals 6.

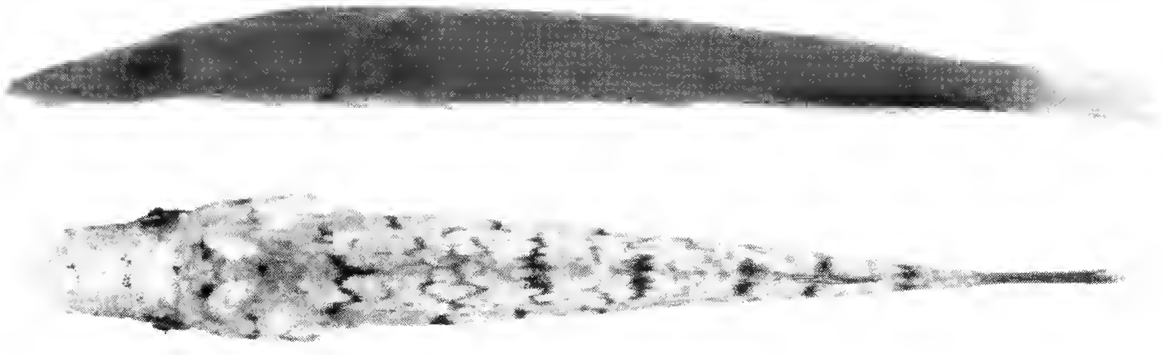

Figure 1 *Cochleoceps spatula:* (a) SAM F.3600, 47 mm SL, lateral view; (b) WAM P.27881-001, 41 mm SL, showing dorsal colour pattern (part of upper lip missing).

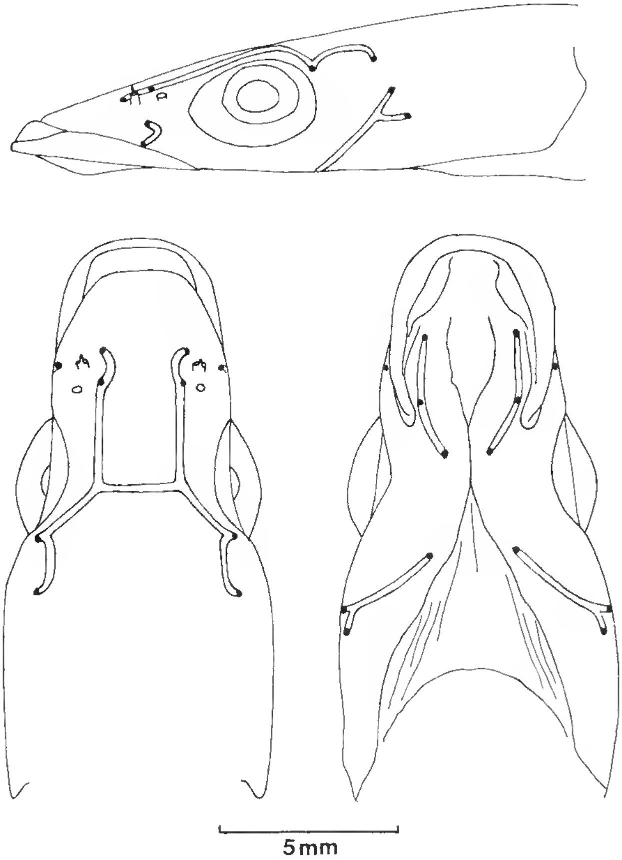

Figure 2 Diagram of the cephalic pore system of *Cochleoceps spatula*, SAM F.3600, 47 mm SL (pores represented by black dots, the underlying canals outlined by solid lines), lateral, dorsal and ventral views (drawn with the aid of a camera lucida).

Table 1 Measurements (mm) of the holotype and selected non-type specimens of *Cochleoceps spatula*.

	Holotype BMNH 1847.7.21.86	SAM F.1474	SAM F.3600	WAM P.26455 -013	WAM P.26455 -013
Standard length	37	57	47	27	23
Head length	12	19	16	9.5	8.4
Head width	4.7	8.5	7.6	4.0	3.4
Body depth	3.3	5.3	4.4	2.1	1.5
Body width	4.5	7.7	6.6	3.3	2.5
Snout length	4.0	6.7	5.8	3.1	2.7
Eye diameter	2.7	4.0	3.6	2.6	2.3
Bony interorbital width	2.4	3.6	3.0	1.6	1.3
Snout to origin of dorsal fin	27	45	37	21	17
Caudal peduncle length	4.6	5.7	4.3	2.1	3.0
Caudal peduncle depth	1.5	2.5	2.1	1.3	1.0
Caudal fin length	7.0	9.2	8.4	5.0	3.4
Ventral disc length	5.8	9.5	9.1	4.5	3.4
Ventral disc width	3.8	6.4	5.4	3.5	2.4

Table 2 Fin ray counts for non-type specimens of *Cochleoceps spatula*.

Dorsal fin rays				Anal fin rays			Pectoral fin rays			
4	5	6	7	6	7	8	17	18	19	20
2	8	14	1	5	11	9	2	5	9	7

Body elongate, subcylindrical (moderately depressed anteriorly, tapering to a compressed caudal peduncle), depth 11.2 (10.2-15.3) and width 8.2 (7.1-9.8), both in SL; caudal peduncle moderately long, depth 3.1 (1.6-3.1) in its length; head flat, depressed, length 3.1 (2.6-3.1) in SL and width 2.6 (2.1-2.6) in head length; snout rectangular in shape (dorsal view), slightly longer than wide, length 3.0 (2.8-3.1) in head length and 1.2 (1.1-1.3) in head width; nostrils located well forward of eye; anterior nostril tubular with a simple triangular flap on posterior half of rim, flap reaching about half way to posterior nostril when folded backwards; posterior nostril with a low raised rim, higher in front; eye with a large clear cornea, diameter 4.4 (3.7-5.0) in head length, slightly greater than bony interorbital width (5.0 [4.8-6.5] in head length).

Skin smooth and scaleless, usually covered by a thick mucous layer; two sensory systems present; first consists of well-developed pores found only on head (Figure 2); each pore usually has a short, tubular opening slightly longer than thickness of mucous, and served by a canal in the underlying bone (outlines of canals indicated in Figure 2); a total of 12 open pores on each side of head is made up of two lacrymal pores, two nasal canal pores, two postocular pores and six preoperculomandibular pores (three associated with each bone); second system consists of minute papillae arranged in consistent patterns on head and body, those on latter in two longitudinal series (because of the difficulty in detecting these papillae they are not described further here).

Gill openings wide, membranes joined across isthmus, but not attached to it, upper attachment of gill membranes opposite first pectoral fin ray; upper attachment of pelvic fin membrane opposite twelfth (10-13th) pectoral fin ray; upper attachment of axial dermal flap opposite sixth-seventh pectoral fin ray; ventral disc double, small to moderate in size, length 6.4 (5.2-6.7) and width 9.7 (7.7-9.7), both in SL; disc papillae arranged as in Figure 3a, those in peripheral series usually increasing in number with increasing SL (poorly preserved or old material may lack some or all papillae).

Mouth inferior, upper lip projecting well forwards of lower lip; teeth in both jaws conical, posteriorly curved and small to moderate in size; lateral teeth uniserial, expanding to 4-6 series anteriorly to form a tooth patch on either side of symphysis; anterior teeth in lower jaw project forwards at about 45°; palatine and vomerine teeth absent; three gills on each side; second gill arch with about five short gill rakers.

Both fin rays and bases of dorsal and anal fins short, base of anal fin slightly longer and originating below or anterior to dorsal fin; snout to origin of dorsal fin 1.4 (1.2-1.4) in SL.

Subopercular element present, forming terminal bone posteriorly on side of head, not spine-like; dorsal postcleithral bone reaches as high as seventh pectoral fin ray; ventral postcleithral bone without serrations and shaped as in Figure 4a.

Colour in alcohol: after more than 120 years in preservative the holotype is an overall brown colour. The non-type material ranges from dark brown to pale yellowish-brown, the latter variation often with 6-7 darker indistinct cross bars along the back.

Colour when fresh (based on dorsal view colour transparencies of two recently collected specimens): ground clour pale green to pale brown with many closely packed very small brown spots, many of which merge to form short darker lines and blotches on head and body (Figure 1b); six short brown bars across back, first above gill opening, last on caudal peduncle; a row of dark brown blotches on mid-side of body; small white blotches present on larger individuals, usually scattered on head and body; occasionally these blotches may be larger and more numerous, giving a piebald appearance.

Distribution

Cochleoceps spatula is known from Port Gawler (34°40′S, 138°26′E), north of Adelaide in South Australia to Fremantle (32°03′S, 115°44′E) in Western Australia. It has been collected by both beach seine and beam trawl from *Posidonia* seagrass beds in depths to 10 m.

Comparisons

The closest relative to *Cochleoceps spatula* is an undescribed species, *Cochleoceps* species 1, so far known only from south-western Australia. Both are elongate species with similar colorations, cephalic pore configurations and ventral disc papillae patterns. However, the latter possesses a much shorter snout (wider than long) with the posterior nostril behind the eye's anterior margin (anterior to margin in *C. spatula).* Also, the anterior teeth on its lower jaw are greatly enlarged, incisorlike, and project forwards almost horizontally, a condition not found in *C. spatula.*

Cochleoceps spatula is easily separated from *C. bassensis* sp. nov. (described below) on the basis of the latter's more robust form, its shorter more triangular-shaped snout, more posteriorly placed nostrils, different cephalic pore configuration (one less preopercular pore, see Figure 6), differently shaped pelvis and postcleithral bones (Figure 4) and different anal and pectoral fin ray counts (5-6 v. 6-8 for *C. spatula*, and 24-26 v. 17-20 respectively). Furthermore, *C. bassensis* sp. nov. is apparently covered with bright red spots in life, while the colour pattern of *C. spatula* consists of brown spots, lines, bars and blotches.

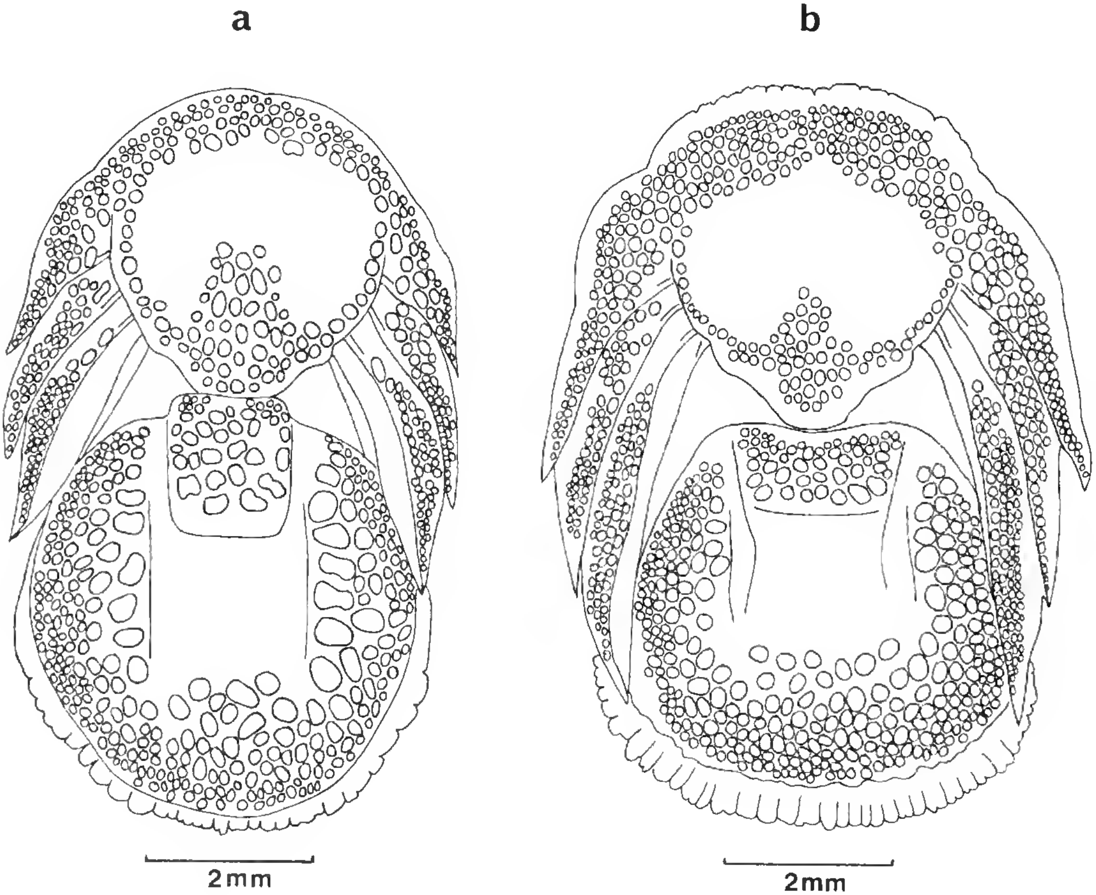

Figure 3 Ventral sucking discs showing arrangement of papillae of (a) *Cochleoceps spatula,* SAM F.3600, 47 mm SL, and (b) *C. bassensis* sp. nov., QVM 1979/5/79, 30 mm SL (camera lucida drawings).

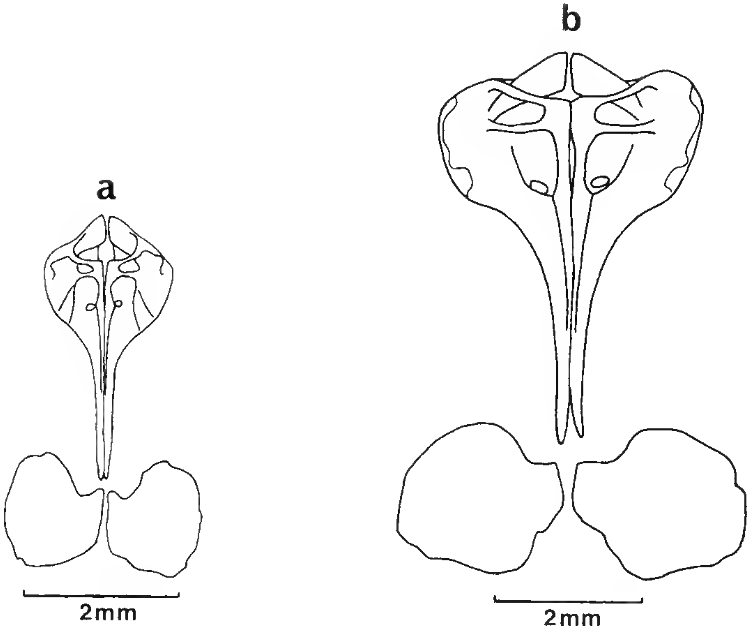

Figure 4 Pelvic and ventral postcleithral bones (ventral view) of (a) *Cochleoceps spatula*, WAM P.26604-008, 39 mm SL, and (b) *C. bassensis* sp. nov., WAM P.27750-001, 40 mm SL (camera lucida drawings of cleared and stained material).

Remarks

Cochleoceps spatula was described (as *Crepidogaster spatula)* by Günther in 1861 from a 44 mm Western Australian specimen collected off the mouth of the Swan River, Fremantle, in an area known as Gage Roads (incorrectly referred to by Günther as 'Gages Road'). Unfortunately most subsequent authors have incorrectly applied this name to a species inhabiting the Bass Strait area of Victoria and Tasmania, commencing with Waite (1906), who presented a detailed description and illustration of this south-eastern Australian clingfish, which although related to Günther's fish, is nevertheless a distinct species. Furthermore, Briggs (1955) reinforced this error by redescribing *C. spatula* from Bass Strait material only (at the time specimens from Western Australia, other than the holotype which was not examined, were unavailable). Because the Bass Strait species has always been incorrectly identified with *C. spatula,* it therefore remains undescribed. The following species account presents a description of *C. bassensis* sp. nov. based on material from Victoria and Tasmania.

Associated with this confusion is the problem concerning the correct identity of the type species of *Cochleoceps* Whitley (1943). This genus was described to accommodate Günther's *Crepidogaster spatula*. The type species of *Crepidogaster* Günther, 1861 (preoccupied = *Aspasmogaster* Waite, 1907) is *Aspasmogaster tasmaniensis,* also described by Günther (1861). In separating these two species, Whitley relied on differences between a figure of *A. tasmaniesis* in Scott (1936) and that of *'Crepidogaster spatula'* from Waite, 1906 (see Figure 7). As noted above, Waite's illustration is based on a Bass Strait specimen and does not depict the true *C. spatula*. However, Whitley also referred to some of the diagnostic features of *C. spatula* given in the original description. Thus Whitley's description of *Cochleoceps* was unknowingly based on two species, *C. spatula* from Western Australia and *C. bassensis* sp. nov. from Bass Strait. Nevertheless, the Western Australian species must remain as the type of *Cochleoceps* because Whitley both designated it as such and supplied enough information to identify it. This may be important if *C. bassensis* sp. nov. proves to be generically distinct from *C. spatula* (see Remarks in the following species account).

Material Examined

Cochleoceps spatula, 29 specimens, 23-57 mm SL. Western Australia: BMNH 1847.7.21.86, holotype, 37 mm SL, Gage Roads, off Fremantle; AM I.23368-001, 40 mm SL, Woodman Point, Cockburn Sound, 17 October 1981; WAM P.21336, 27 mm SL, Forest Beach, Geographe Bay, January 1972; WAM P.26455-013, 10 specimens (one cleared and stained), 23-40 mm SL, off Wonnerup estuary, Geographe Bay, 25 December 1977; WAM P.26604-008, 5 specimens (one cleared and stained), 38-41 mm SL, off Emu Point, King George Sound, 15 April 1980. South Australia (all specimens at SAM): F.1474, three specimens, 40-57 mm SL, Port Gawler, 11 February 1931; F. 3600, four specimens, 43-48 mm SL, Foul Bay, Yorke Peninsula, December 1965; F.3606, four specimens, 43-53 mm SL, Wool Bay, Yorke Peninsula, 10 December 1965.

Cochleoceps species 1, 17 specimens from Western Australia, 14-40mm SL (all at WAM): P.26455-011, five specimens, 14-22 mm SL, off Wonnerup estuary, Geographe Bay, 25 December 1977; P.26604-009, seven specimens (one cleared and stained), 30-40 mm SL, off Emu Point, King George Sound, 15 April 1980; P.26622-004, five specimens, 29-34 mm SL, Thomson Bay, Rottnest Island, 16 June 1980.

Cochleoceps bassensis sp. nov.

Figures 3b, 4b, 5, 6, 7; Table 3, 4

Crepidogaster spatula — Waite, 1906: 201, pl. 36, Fig. 4.

Aspasmogaster spatula — Waite, 1921: 179, figure; Waite, 1923: 206, figure; McCulloch, 1929: 359 (part); Scott, 1936: 119 (part).

Cochleoceps spatula — Whitley, 1943: 141 (part); Whitley, 1954: 29; Scott, 1954: 110; Briggs, 1955: 52, Fig. 29; Scott, 1962: 286, figure; Scott *et al.,* 1974: 318, figure; Glover, 1982: 14.

Holotype

AM I.23367-001, 50 mm SL, Western Port, Victoria (38°26′S, 145°08′E), J. Gabriel, no other data.

Paratypes

Eleven specimens, 6-50 mm SL.

Victoria

AM I.7607, two specimens, 35-50 mm SL, same collection data as for holotype; NMV A.2828, 28 mm SL, off Stony Point, Western Port, trawled in 16 m, Department of Fisheries and Wildlife *(Caprella),* 1 June 1967.

Tasmania

AM E.1001, 38 mm SL, Oyster Bay, trawled by F.R.V. *Endeavour;* AM I.10410, 47 mm SL, Oyster Bay, trawled by F.R.V. *Endeavour,* 13 September 1909; AM I.13005, 26 mm SL, Wineglass Bay, at 20 m, E.A. Briggs; NMV A.1730, 6 mm SL, south-western Bass Strait (40°38′S, 145°23′E), dredged in 36

Figure 5 *Cochleoceps bassensis* sp. nov. holotype, AM I.23367-001, 50 mm SL, lateral and dorsal views (right-hand side of upper lip damaged).

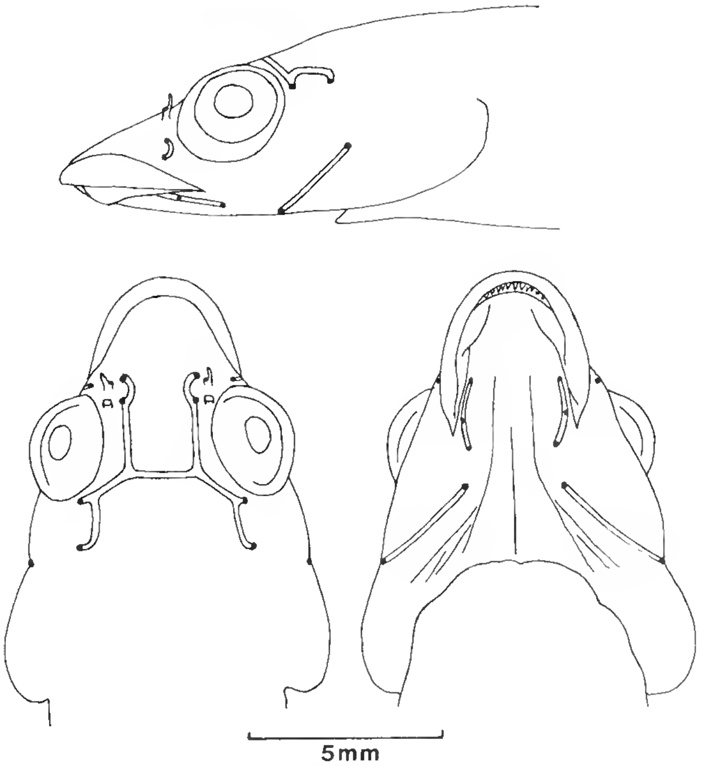

Figure 6 Diagram of the cephalic pore system of *Cochleoceps bassensis* sp. nov., QVM 1979/5/79, 30 mm SL (pores represented by black dots, the underlying canals outlined by solid lines), lateral, dorsal and ventral views (drawn with the aid of a camera lucida).

m, G. Poore on board F.V. *Sarda,* 4 November 1980; NMV A.2298, 32 mm SL, southern-western Bass Strait (40°22′S, 145°17′E), dredged in 40 m, M. Gomon *et al.* on board F.V. *Sarda,* 3 November 1980; WAM P.27750-001, 40 mm SL (cleared and stained), same collection data as for previous specimen; QVM 1979/5/44, 37 mm SL, Binnalong Bay, 28 April 1979; QVM 1979/5/79, 30 mm SL, 3 km NE of Eddystone Point (Stn 342), 27-36 m, 11 July 1979.

Diagnosis

This species is placed in the genus *Cochleoceps* on the basis of its ventral disc papillae pattern (Figure 3b). It can be distinguished from the other members of the genus by the large, more triangular-shaped snout, all others possessing either rectangular-shaped snouts, or short, rounded ones.

Description

Measurements and counts of the holotype and selected paratypes are presented in Tables 3 and 4. The following counts and proportions in parentheses represent the ranges for the paratypes when they differ from those of the holotype.

Dorsal fin rays 6(5-6); anal fin rays 6 (5-6); pectoral fin rays 25(24-26), pelvic fin rays I,4; caudal fin rays 12 (11-12); vertebrae 33-34; branchiostegals 6.

Body robust, moderately depressed anteriorly and compressed posteriorly, depth 5.6 (4.7-6.6) and width 4.2 (4.1-5.1), both in SL; caudal peduncle prominent, depth 0.9 (0.7-1.1) in its length; head wide, moderately depressed, length 2.4 (2.4-2.5) in SL, width 1.5 (1.3-1.6) in head length; snout triangular in shape (dorsal view), rounded anteriorly, length 2.9 (2.9-3.2) in head length and 1.9 (1.9-2.4) in head width (snout relatively more narrow in females); anterior nostril located just in front of anterior margin of eye, posterior nostril just behind anterior margin of eye; both nostrils tubular, anterior more prominent with a simple pointed flap on posterior half of rim reaching to or behind posterior nostril when folded backwards; eye moderate, diameter 5.1 (4.1-5.1) in head length; bony interorbital width about equal to eye diameter or, in large specimens, somewhat greater, width 4.0 (4.0-4.8) in head length.

Skin smooth and scaleless, usually covered with a thick mucous layer (a series of transverse skin ridges on body are probably due to shrinkage during preservation); two sensory systems present, similar in shape and position as described for *C. spatula,* except that preopercular series consists of two open pores instead of three (compare Figures 2 and 6).

Gill openings wide, membranes joined across isthmus but not attached to it; upper attachment of gill membrane opposite third (3-5th) pectoral fin ray; upper attachment of axial dermal flap opposite thirteenth (12-14th) pectoral fin ray; upper attachment of pelvic fin membrane opposite fifteenth (13-15th) pectoral fin ray; ventral disc double, moderate to large in size, length 3.3 (3.2-3.9) and width 4.2 (3.2-5.1), both in SL; disc papillae arranged as in Figure 3b, those in peripheral series usually increasing in number with increasing SL (papillae in single series which flanks bases of pelvic fin rays often lost, compare Figure 3b with Figure 29 in Briggs 1955).

Mouth terminal to slightly inferior, upper lip generally projecting farther forward than lower lip; lateral teeth in both jaws uniserial, conical, posteriorly curved and moderate in size; in upper jaw lateral series continued anteriorly, with a patch of much smaller similarly shaped teeth on either side of symphysis; in lower jaw the symphysial patch is continued anteriorly, the anteriormost series projecting forwards and more worn than those behind; palatine and vomerine teeth absent; three gills on each side; second gill arch with seven short gill rakers.

Both fin rays and bases of dorsal and anal fins short, bases generally equal in length; origin of dorsal fin over or slightly in front of anal fin; snout to dorsal fin origin 1.3 (1.2-1.3) in SL.

Subopercular element present, forming terminal bone posterity on side of head, not spine-like; dorsal postcleithral bone reaches as high as thirteenth pectoral fin ray; ventral postcleithral bone without serrations and characteristically shaped (Figure 4b).

Table 3 Measurements (mm) of the holotype and selected paratypes of *Cochleoceps bassensis.*

	Holotype	Paratypes			
	AM I.23367-001	AM E.1001	NMV A.2298	QVM 1979/5/79	NMV A.2828
Standard length	50	38	32	30	28
Head length	21	16	13	12	11
Head width	14	9.7	8.0	8.1	7.5
Body depth	9.0	5.8	6.6	5.0	4.5
Body width	12	8.8	6.5	5.9	6.6
Snout length	7.3	5.2	4.1	4.0	3.6
Eye diameter	4.1	3.5	3.0	2.7	2.7
Bony interorbital width	5.3	3.6	2.7	2.7	2.5
Snout to origin of dorsal fin	38	29	27	24	22
Caudal peduncle length	4.3	2.5	3.0	2.8	2.7
Caudal peduncle depth	4.9	3.7	2.7	2.7	2.6
Caudal fin length	8.6	7.3	*	5.9	5.4
Ventral disc length	15	9.8	8.9	9.0	8.3
Ventral disc width	12	7.5	7.3	6.5	7.1

* Measurement not taken because of damaged fin.

Table 4 Fin ray counts for type specimens of *Cochleoceps bassensis.*

Dorsal fin rays		Anal fin rays		Pectoral fin rays		
5	6	5	6	24	25	26
1	9	1	9	3	3	2

Colour of holotype in alcohol: after many years in preservative the holotype is an overall pale brown colour. The colour of the paratypes ranges from pale brown to dark brown, except for two of the more recently collected specimens from Tasmania (at QVM). Their ground colour is pale yellow, the back and upper sides profusely covered with red stipple-like spotting, the undersides being more sparsely spotted; this spotting is continued on to the fin rays of the dorsal, anal, pelvic and caudal fins (the pectoral fins are unspotted); aggregations of these spots indicate the original presence of much larger spots (see Figure 7), the colour having generally faded.

Colour in life: apparently covered with bright red spots (Figure 7). See also following discussion under Remarks.

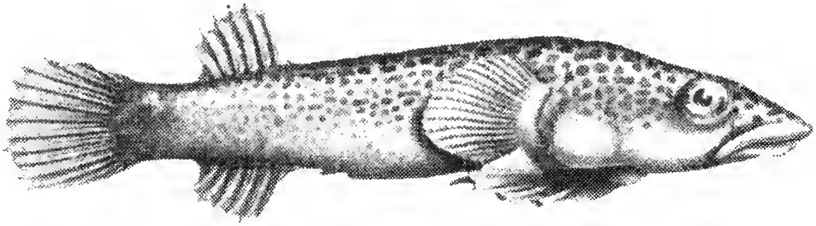

Figure 7 Waite's (1906) illustration of "*Crepidogaster spatula*" (= *Cochleoceps bassensis* sp. nov.) showing diagnostic colour pattern.

Distribution

Cochleoceps bassensis is known from both sides of Bass Strait, from Western Port in Victoria (38°22′S) 145°32′E) to the north-eastern and north-western corners of Tasmania. As well it has been found on Tasmania's east coast as far south as Wineglass Bay (42°10′S, 148°18′E) on Freycinet Peninsula (it may also occur in South Australia, see Remarks section below). It has been taken by both bottom trawl and dredge on sandy bottoms at depths to 40 m.

Comparisons

The differences between *Cochleoceps bassensis* and *C. spatula* were discussed in the account of the latter species. It is separable from the undescribed *Cochleoceps* species 1 from Western Australia by the latter's more elongate form (similar to *C. spatula)* and large incisor-like teeth in the lower jaw. The so-called 'cleaner clingfishes' *Cochleoceps* species 2 from Western Australia, South Australia and Victoria (see Scott *et al.*, 1980: pl. 13), and *Cochleoceps* species 3 from New South Wales, both of which are undescribed, have recently been confused with *C. bassensis* (all three species are covered with close-packed red spots). However, these species have narrow blue cross bars on their backs, a feature absent in *C. bassensis*. In addition, they are smaller (maximum known size of 30 mm SL as against 50 mm SL), have short rounded snouts instead of a prominent triangular-shaped one and possess fewer sensory pores on the mandible (two v. three on each side). Species of the genus *Aspasmogaster* differ from *C. bassensis* by possessing completely different patterns of ventral disc papillae (they lack the triangular patch located posteriorly on the midline of the disc's anterior half, see Scott *et al.* 1974: 318). In addition, *Aspasmogaster* possesses only one sensory pore in the mandibular series, which is directly connected to the preopercular series, and has three lacrymal pores. *Cochleoceps bassensis* possesses three mandibular pores which are not directly connected to the preopercular series, and its lacrymal series consists of only two pores (a review of *Aspasmogaster* is in preparation by the present author).

Remarks

Although *Cochleoceps bassensis* differs considerably in body shape from *C. spatula,* they are nevertheless closely related (see remarks in species account for *C. spatula).* However, within the genus *Cochleoceps* there appears to be three natural groups which may be diagnosed as follows:

1. Elongate body and six preoperculomandibular pores *(C. spatula* and *C.* species 1).
2. Robust body and five preoperculomandibular pores *(C. bassensis).*
3. Moderately robust body and four preoperculomandibular pores (*C.* species 2 and *C.* species 3).

Further studies may show that more than one genus is represented here, but for the present all five species are retained in *Cochleoceps.*

With regard to the life colours of *C. bassensis,* little information is available. Waite's 1906 description and illustration of '*C. spatula*' (= *C. bassensis*) indicate that it is covered with 'crowded carmine spots, those on head round, those on the body lengthened' (see Figure 7). However, Waite's material was sent to him in Sydney from Melbourne so it was most likely preserved before despatch. Nevertheless, enough of the coloration must have remained for Waite to prepare his description. Judging by the colour differences observed by the present author between live and recently preserved material of both *Cochleoceps* species 2 and *C.* species 3, there seems little doubt that in life *C. bassensis* is covered with closely packed bright red spots. Life colours referred to '*C. spatula*' by Scott 1976, were taken from northern Tasmania specimens of a species characterized by obvious spine-like subopercular bones, a feature lacking in all species of *Cochleoceps.* Thus Scott's description is not of *C. bassensis,* his specimens apparently representing a new genus and species.

As noted above, Waite's description and illustration were made from specimens sent to him by the collector. These are still extant and in reasonable condition (they formed the basis of Briggs' 1955 description of '*C. spatula*', but were incorrectly listed as I.7606 from Port Phillip Bay). The specimen most likley to have been the subject for Waite's figure has been selected as the holotype for *C. bassensis.*

Cochleoceps bassensis has been included (as *C. spatula*) in numerous accounts on South Australian fishes (Waite 1921, 1923; Scott [T.D.] 1954, 1962; Scott *et al.* 1974, 1980; and Glover 1979, 1982). However, no specimens could be located to substantiate these records. The first inclusion was by Waite (1921) who simply added South Australia to is distribution without further comment. Scott (1962) stated that the 'species is rare in South Australia'. However, until positive proof of its presence is made available, these South Australian records must be open to doubt.

This species is named *bassensis* with reference to its Bass Strait distribution.

Additional Material Examined

Cochleoceps species 2, three specimens, 18-29 mm SL. Western Australia (all at WAM): P.26608-025, 20 mm SL (cleared and stained), Lookout Point, east of Albany, 19 April 1980; P.26616-002, 18 mm SL, Rottnest Island, 7 June 1980. South Australia: NMV A.2829, 29 mm SL, Flinders Island, 29 March 1982.

Cochleoceps species 3, six specimens, 19-24 mm SL. New South Wales: AM I.21975-001, 19 mm SL, The Haven, Terrigal, 26 February 1977; NMV A.2830, 24 mm SL, Montague Island, 15 September 1981; WAM P.27103-001, four specimens (one cleared and stained), 21-22 mm SL, Big Island, Wollongong, 3 February 1981.

Gobiesocid species (with subopercular spines) from Tasmania: QVM 1980/5/17, six specimens, 25-29 mm SL, Eddystone Point, November 1979.

Acknowledgements

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A New Species of the Prosobranch Gastropod *Glacidorbis* and its Implications for the Biogeography of South-Western Australia

Stuart E. Bunn* and James A. Stoddart*[1]

Abstract

Minute snails found in streams of the Darling Range, Western Australia, are described here as a new species, *Glacidorbis occidentalis*. *Glacidorbis* has a southern distribution, occurring in south-eastern Australia, Tasmania, and southern Chile. Its presence in south-western Australia is consistent with theories proposing a common Gondwanic origin for much of this region's freshwater fauna and that of south-eastern Australia.

Introduction

As faunal and floral surveys become increasingly intensive, a better understanding of biogeographic patterns is achieved. This is especially true for groups of minute or cryptic organisms. Here, the discovery of a particularly small gastropod during an ecological study of the invertebrate fauna of streams in the Darling Range, Western Australia, provides an important link between the freshwater faunas of south-western and south-eastern Australia.

This paper describes the snail as a new species of the genus *Glacidorbis* Iredale, 1943. Occurrences of other members of this genus have been used recently to demonstrate zoogeographic relationships between south-eastern Australia, Tasmania and South America (Meier-Brook and Smith 1975; Smith 1979). The significance of its occurrence in south-western Australia is discussed in context with past and present views on the biogeography of this region.

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[1] Order randomly determined.

Systematics

Family ?Hydrobiidae[2]

Genus *Glacidorbis* Iredale, 1943

***Glacidorbis occidentalis* sp. nov.**

Figures 1-7

Holotype

WAM 778.82 from Wungong Brook, Jarrahdale, at the Chandler Bridge (32°17′S, 116°08′E) Western Australia. Collected by S. Bunn, 21 July 1982.

Paratypes

WAM 779.82 from Dillon Brook, North Dandalup, Western Australia (32°30′S, 116°04′E). Collected by S. Bunn, 23 July 1982, 3 specimens. WAM 780.82 from Seldom Seen Brook, Jarrahdale, Western Australia (32°16′S, 116°06′E). Collected by S. Bunn, 2 July 1982, 2 specimens.

Diagnosis

A small species of *Glacidorbis* with a shell not more than 1.20 mm diameter at 2.5 whorls; radula of 19-20 rows of teeth, each with a single short mesocone bearing 2-5 denticles on either side.

Description

Shell minute, planispiral, flattened dorsally, concave ventrally, smooth, with fine growth lines (Figure 1). Maximum diameter 1.20 mm; apertural diameter 0.5 mm at 2.6 whorls. Periostracum fine, brown, often fringing the aperture lip. Operculum thin, corneous, paucispiral with a number of whorls equivalent to that of the shell (Figure 2).

Radula with 19-20 rows of teeth (Figure 3), each row consisting of a single triangular mesocone. Mesocones bear 2-5 pointed cusps on either side (Figures 4-5); cusps may be broken off or worn and are absent on older teeth (Figure 6); marginals absent.

Live animals vary in colour from cream to dark grey as amounts of pigment vary between sites. The foot is bifurcated posteriorly and palps on the anterior head produce a similar bilobed appearance (Figure 7). Developing embryos, seen through the shell of some specimens, appear to be distributed from the rear of the mantle posteriorly into the region of the digestive gland. No gills were seen. The small size of the snail prevented a more detailed dissection.

The species is named *occidentalis* as it is the most western *Glacidorbis* recorded.

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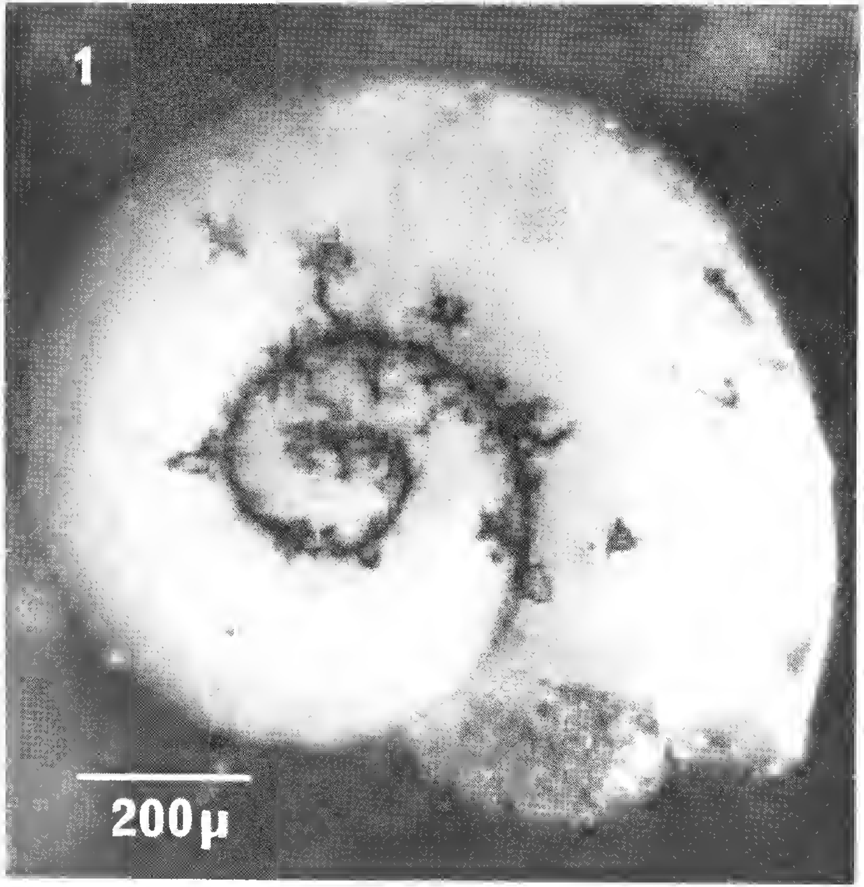
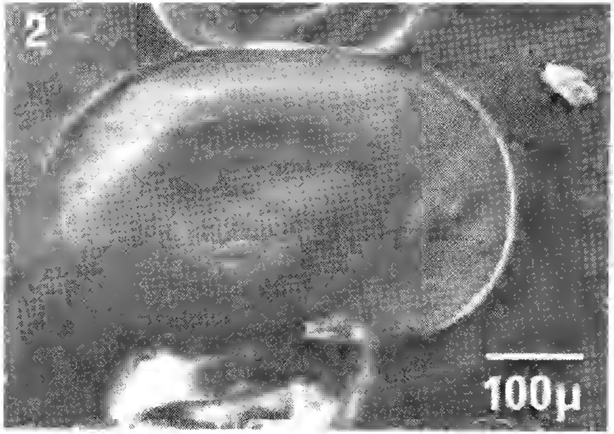
[2] The familial placement of the genus is uncertain and is under review by Dr B.J. Smith of the National Museum of Victoria.





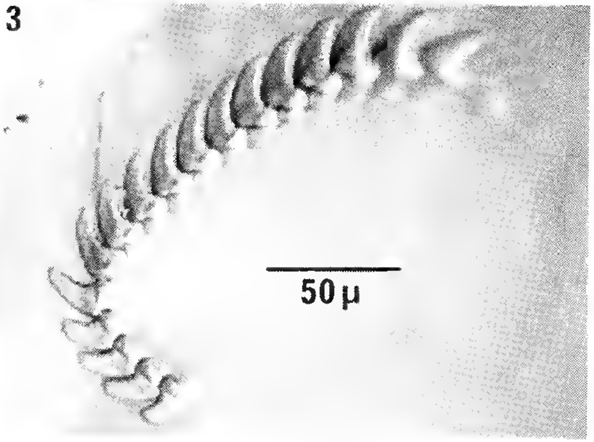
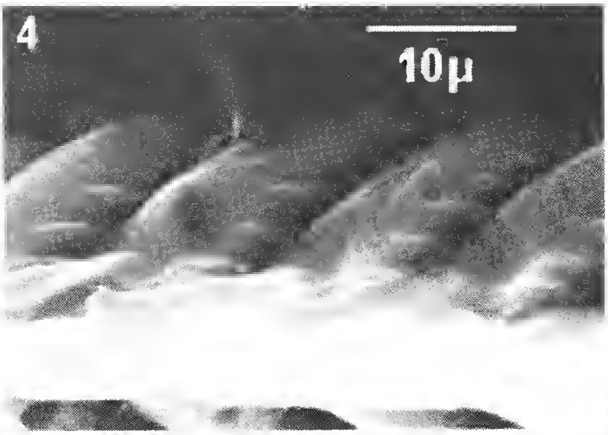
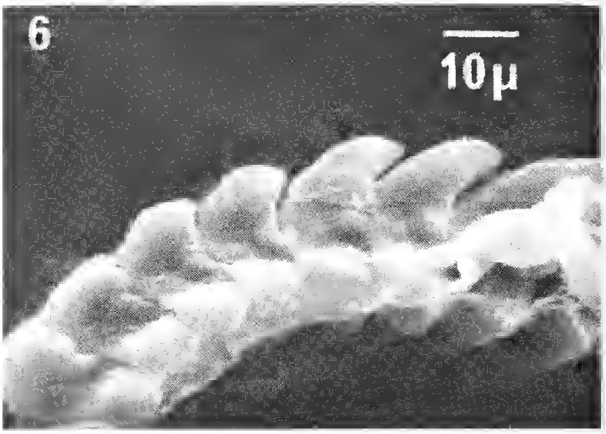
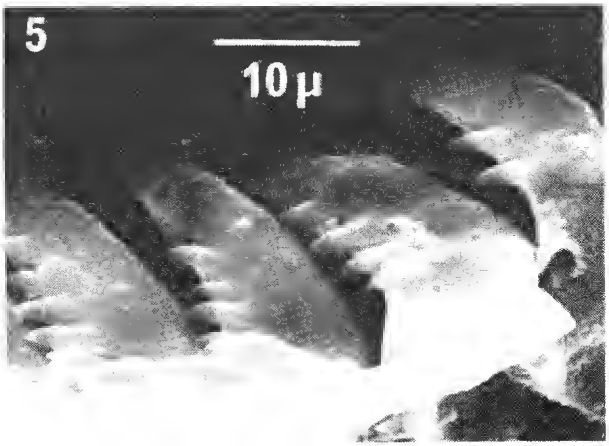


Figure 1 Shell of *G. occidentalis* from Wungong Brook, dorsal aspect.
Figure 2 Exterior surface of operculum of specimen from Wungong Brook.
Figure 3 Radula of specimen from Dillon Brook.



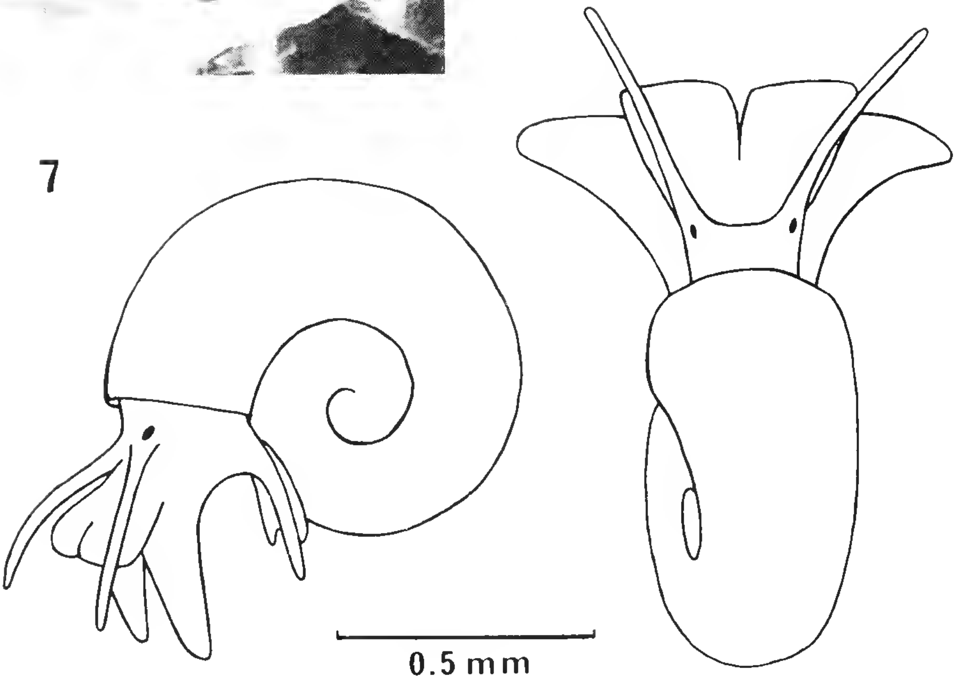




Figures 4, 5 Radula of specimen from Wungong Brook showing teeth and cusps.

Figure 6 Radula of specimen from Wungong Brook showing worn teeth.

Figure 7 Drawing showing head and foot of live specimen from Wungong Brook.



Dimensions

Specimen	Maximum diameter (mm)	Aperture diameter (mm)	Whorls
Holotype WAM 778.82	0.96	0.44	2.3
Paratypes WAM 779.82	0.84	0.36	2.1
,,	1.08	0.40	2.2
,,	0.68	0.32	1.6
WAM 780.82	1.20	0.48	2.6

Other Material Examined

Western Australia:

Wungong Brook, Jarrahdale, 14 specimens, S. Bunn, 17/ix/1981; Dillon Brook, North Dandalup, 10 specimens, S. Bunn, 19/ix/1981; Wungong Brook, Jarrahdale, 2 specimens, S. Bunn, 2/xii/1981; Dillon Brook, North Dandalup, 6 specimens, S. Bunn, 4/xii/1981; Wungong Brook, Jarrahdale 2 specimens, S. Bunn, 20/i/1982; Seldom Seen Brook, Jarrahdale, 1 specimen, S. Bunn, 20/i/1982; Wungong Brook, Jarrahdale, 6 specimens, S. Bunn 4/iii/1982; Wungong Brook, Jarrahdale, 19 specimens, S. Bunn, 2/vi/1982; Seldom Seen Brook, Jarrahdale, 4 specimens, S. Bunn, 2/vi/1982; Wungong Brook, Jarrahdale, 2 specimens, S. Bunn 21/viii/1982; Dillon Brook, North Dandalup, 2 specimens, S. Bunn, 23/vii/1982. This material is currently held in the Department of Zoology, University of Western Australia.

Description of Habitat

The snails were found in three of six streams sampled in jarrah forest on the western edge of the Darling Range, south of Perth, Western Australia. This is a dry sclerophyll forest dominated by jarrah *(Eucalyptus marginata)* and to a lesser extent marri *(E. calophylla)* (Gardner 1942). The climate is typically Mediterranean with a yearly rainfall of approximately 1250 mm, of which approximately 85% falls between May and October (Seddon 1972).

Although many rivers and streams in this region flow intermittently, some headwater streams arising from spring-fed swamps flow all year. The southern branch of the Wungong Brook, and Seldom Seen Brook near Jarrahdale are perennial streams in a catchment currently strip-mined for bauxite. Dillon Brook is a small intermittent stream in the North Dandalup catchment approximately 20 km south of Jarrahdale. All three streams are in the highest rainfall area of the Darling Range (1200-1400 mm). Similar streams are present to the south of these but were not sampled in the present study and it may be that the distribution of *G. occidentalis* is more extensive than recorded here.

Snails were taken from gravel riffle sections of the streams with a Surber sampler (0.10m^2; 475 μm mesh net). Specimens for dissection were narcotized with menthol crystals and preserved in 70% ethyl alcohol. All other material was fixed in 4% formalin and preserved in 70% ethyl alcohol. Streams were sampled at approximately six-weekly intervals beginning in September 1981, with the exception of Dillon Brook which was dry from December 1981 until May 1982. Table 1 summarizes some of the chemical and physical characteristics of these streams.

Table 1 Some chemical and physical features of the three streams where *G. occidentalis* have been found. The mean, range and number of measurements made from September 1981 to August 1982 are presented.

		Temp. °C	pH	Depth cm	D.O. mg/1	Na^+ mg/1	K^+ mg/1	Mg^{2+} mg/1	Ca^{2+} mg/1
Wungong Brook	$\bar{x}$	14.5	6.3	17	8.2	39.9	1.2	2.6	5.2
(permanent)	range	9.5-19.0	6.15-6.50	6-31	6.0-10.8	29.0-46.6	0.7-1.5	1.8-3.5	3.7-6.4
	(n)	8	6	8	5	7	7	7	7
Seldom Seen Brook	$\bar{x}$	16.5	6.3	15	9.0	34.4	1.1	2.1	4.8
(permanent)	range	11.0-21.5	6.20-6.45	8-24	8.1-10.2	27.6-38.0	0.7-1.4	1.8-2.7	3.8-5.7
	(n)	8	6	8	5	7	7	7	7
Dillon Brook	$\bar{x}$	15.0	6.4	6	10.4	33.8	1.2	1.6	3.9
(intermittent)	range	11.0-19.0	6.30-6.50	0-15	–	29.4-36.9	0.8-1.5	1.1-2.1	3.4-4.3
	(n)	5	3	8	1	4	4	4	4

Table 2 Shell and radular characters of the five described species of *Glacidorbis*, derived from the text and figures of Smith (1973, 1979) and Meier-Brook and Smith (1975). '1' denotes presence of the character, '0' absence.

Species	**Max. diameter (mm)**	**Av. teeth rows**	**Av. cusps per side**	**Marginal teeth**	$\frac{\textbf{Tooth height}}{\textbf{Depth at base}}$	**Keel**
pawpela	3.5	24.0	18.0	0	4.4	0
hedleyi	3.0	25.0	7.0	0	3.0	0
magallanicus	2.8	28.0	4.5	1	1.1	0
pedderi	1.7	19.0	7.0	0	2.5	1
occidentalis	1.2	19.5	3.5	0	1.6	0

Relationships with Other Species

Comparison of characters obtained from descriptions of other species of *Glacidorbis* with those of *G. occidentalis* (Table 2) shows that although this species is the smallest of the genus, most of its character states are shared. Application of the parsimony assumption through Wagner analysis (Farris 1973) to our rather limited data set (Figure 8) suggests *G. occidentalis* to be most closely related to *G. pedderi*. Although this character set is too meagre to provide a robust basis for testing hypotheses, it is inconsistent with any idea of *G. occidentalis* either having a separate origin from the other species of *Glacidorbis* or representing a western outgroup.

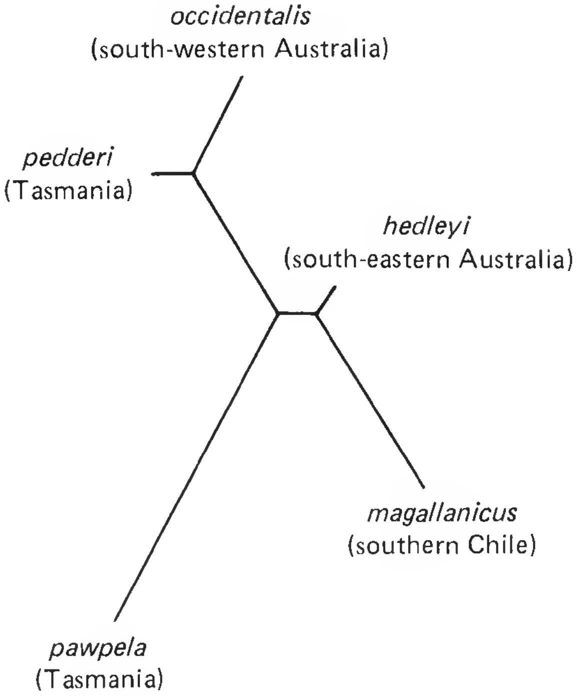


Figure 8 Wagner network for *Glacidorbis* species. Internode distances are proportional to patristic distances.

Discussion

Early workers on Australian biogeography considered the south-west of Western Australia to have such a distinctive flora and fauna that they postulated a separate origin of the south-western and south-eastern biotas (Tate 1887; Hedley 1893; Harrison 1928). Nicholls (1933) recognized a closer relationship between the faunas of south-western and south-eastern Australia but still considered the south-west to be sufficiently distinctive to be regarded as a separate faunal region. A number of terms were proposed by these workers to delineate faunal regions but many of these are now obsolete (see in Jenkins 1982). The south-west is currently considered as the western part of the Bassian Province of temperate southern Australia (MacKerras 1970). Although the fauna of the south-west is distinctive it is predominantly Bassian in relationships.

According to MacKerras (1970) most groups of terrestrial and freshwater invertebrates of the Bassian Province are composed predominantly of southern elements. Such elements, usually apparent at generic level or above, are characterized by their evolutionarily primitive forms and Gondwanic distributions. Many of these elements are shared principally between southern Australia and South America. Further data, collected over the past decade, have supported such an hypothesis (see Keast 1981). The presence of a species of *Glacidorbis* in south-western Australia is consistent with both the common origins of the south-western and south-eastern Bassian faunas and the presence of Gondwanic elements in these origins. A fossil species of *Glacidorbis* has recently been reported from Middle Miocene deposits in the Strzelecki Desert of Central Australia (Buonaiuto 1982) suggesting that the past distribution of *Glacidorbis* was much more extensive than the present. Subsequent contraction of this distribution, perhaps due to climatic effects, has resulted in the present day occurrence of *Glacidorbis* species in often discrete and widely separated pockets.

Reliable zoogeographic indicators should have limited powers of dispersal and/or limited ecological tolerances (MacKerras 1970). Species of *Glacidorbis* appear to meet both of these criteria. Previous collections of *Glacidorbis* species have come from permanent, fresh, slightly acidic waters which remain cold for most of the year and are often subjected to winter snow (Smith 1979). Although the habitat of *G. occidentalis* is substantially different from this, the association of the genus with slightly acidic waters draining peaty swamps still holds. Such areas are not prone to the massive flooding which may act as a dispersal mechanism for some snails; nor is it likely that aerial dispersion by birds, suggested for some pulmonates (Rees 1965), could transfer these tiny prosobranchs to a suitable habitat. The presence of *G. occidentalis* in two separate catchment areas distant from centres of population suggests it has not been introduced by man. Thus, the distribution of the genus *Glacidorbis* is primarily relictual, an indicator of past events.

The distinctiveness of the freshwater fauna of south-western Australia is not the result of a unique origin. Rather, it is probably the result of a combination of factors including, isolation from the northern elements which have subsequently invaded south-eastern Australia, the evolutionary consequences of the episodic nature of much of its freshwater, the lack of certain habitat types, and the separation of its gene pools from those of conspecifics in south-eastern Australia.

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Two New Lizards from Western Australia (Genera *Diplodactylus* and *Lerista*)

G.M. Storr*

Abstract

Two new species of lizard, the gecko *Diplodactylus wilsoni* and the skink *Lerista haroldi,* are described from the arid mid-west of Western Australia.

Introduction

The large genera *Diplodactylus* and *Lerista* are notable for the number of species with extremely circumscribed ranges, e.g. *D. fulleri, D. wombeyi, L. neander* and *L. separanda.* To these we add another two species, *D. wilsoni* and *L. haroldi,* that are only known from a single locality or very small area.

Systematics

Family Gekkonidae

***Diplodactylus wilsoni* sp. nov.**

Figure 1

Holotype

R78932 in Western Australian Museum collected on 28 July 1982 by S.K. Wilson at 25 km NNW of Waldburg, Western Australia, in 24°33′S, 117°14′E.

Paratypes

North-West Division (W.A.)

19 km SW Waldburg (81213-5) and 21 km SW (78931); Mt Clere Station (78930).

Diagnosis

An aberrant rock-inhabiting member of the *D. strophurus* group (Kluge 1967; Russell and Rosenberg 1981) with homogeneous dorsals, without pre-anal pores and without supraciliary or supracaudal spines. Most like *D. rankini* Storr but having a shorter tail, no dorsolateral series of tubercles on body, and a very different colour pattern (faint longitudinal stripes).

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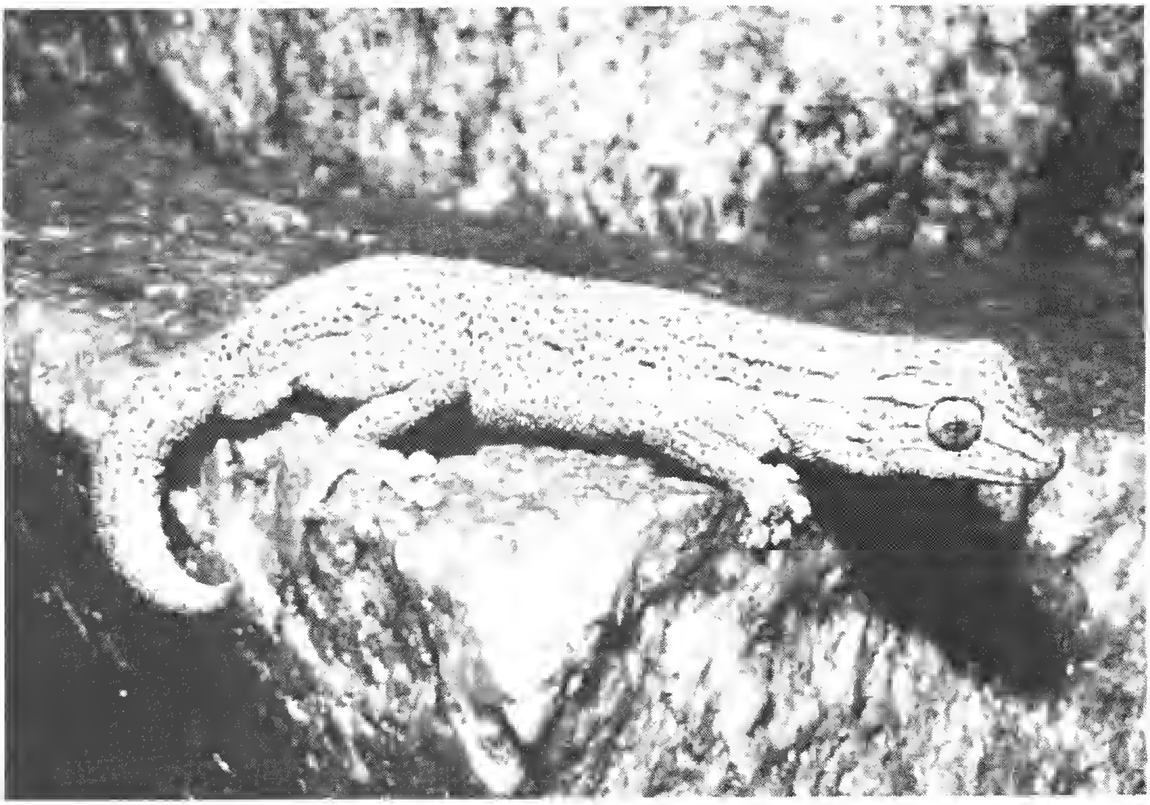

Figure 1 Paratype of *Diplodactylus wilsoni*, photographed in life by S.K. Wilson.

Description

Snout-vent length (mm) 28-56 (N 6, mean 47.5). Length of tail (% SVL): 42-54 (N 6, mean 48.3).

Rostral pentagonal, 2.7-3.4 times as wide as high, and with median groove extending down for 20-50% of height of scale. Nostril surrounded by first labial, rostral, two supranasals and one postnasal. Anterior supranasals much larger than posterior supranasals and separated by one or two small scales. Posterior supranasals separated by 2-4 scales. Interorbitals 19-22. No supraciliary (or other) spines. Upper labials 9 or 10 back to middle of eye. Dorsal scales subconical, a little larger than ventrals. Supracaudal scales heterogenous, some scales being much larger and higher than others. Digits bearing large apical plates; lamellae under fourth toe 5-7, entire (except for a divided lamella at base of toe in one specimen). Pre-anal pores absent in both sexes. Cloacal spur consisting of one or two white obtuse spines.

Upper surfaces brownish-grey except for reddish-brown apices of dorsal scales and for short, wide, finely black-edged, grey longitudinal stripes on head, neck and shoulders (stripes barely discernible, owing to their being only slightly paler than ground colour; remnants of stripes, especially their black edges, sometimes discernible further back on body and on ventral surfaces). Iris greyish-blue, with a fine anastomosis of black lines.

Distribution

Arid mid-western interior of Western Australia.

Remarks

This species is named after its sole collector, Stephen Karl Wilson. All specimens were found in vertical crevices in dolerite and quartz sandstone.

D. wilsoni links the *strophurus* and *michaelseni* groups. In its caudal glands and circumnarial and subdigital scalation, *wilsoni* agrees with the *strophurus* group; but in its colour pattern and lack of pre-anal pores, spines and dorsal tubercles, it approaches the *michaelseni* group. Russell and Rosenberg (1981) unite the *strophurus* and *michaelseni* groups (and *Diplodactylus elderi)* in the subgenus *Strophurus*.

Family Scincidae

***Lerista haroldi* sp. nov.**

Figure 2

Holotype

R81199 in Western Australian Museum collected by G. Harold and C. Winton on 20 May 1982 at 0.5 km S of Gnaraloo HS, Western Australia, in 23°49′S, 113°31′E.

Figure 2 Holotype of *Lerista haroldi*, photographed in life by G. Harold.

Diagnosis

A short-tailed, moderately stout member of the *L. elegans* group (Storr 1972: 72) with 3 fingers, 3 toes and immovable eyelids. Distinguishable from *L. muelleri* by its pale, almost patternless coloration.

Description (of holotype, the only available specimen)

Snout-vent length 39 mm. Length of appendages etc. (% SVL): foreleg 8, hindleg 23, tail 102, snout to foreleg 28.

Nasals in contact. Frontoparietals in long contact, slightly larger than interparietal. Nuchals 2/2. Supraoculars 3, first two in contact with frontal. Supraciliaries 4. Temporals 1 + 2, upper secondary largest, lower secondary smallest. Upper labials 6. Midbody scale rows 20. Lamellae under third toe 14, very weakly keeled.

Upper surfaces pale pinkish-grey (head and back brownish-yellow in life). Top of head and temples finely speckled with dark greyish-brown. Dark brown streak from nostril to eye. Sutures between upper labials brown (barring widest and darkest anteriorly). Back and side of body faintly and very finely speckled with brownish-grey. Tail finely marked with blackish-grey, most strongly on upper surface (where markings mostly taking form of curved transverse lines); markings on lower surface shorter, paler, more broken, and longitudinally orientated. Lower surfaces whitish.

Distribution

Known from one locality on upper west coast of Western Australia.

Derivation of Name

After Gregory Harold, co-collector of the unique specimen.

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An Aboriginal Engraving Site in the South-West of Western Australia

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Abstract

This report extends the known range of Australian Aboriginal rock engravings to the extreme south west corner of Western Australia. The site and the local geology are described with reference to the possible age of the engravings. Consideration is given to both content and typology of motifs. Finally, the problems posed in the conservation of this unique site are considered.

Introduction

An Aboriginal rock engraving site has been located on the south coast of Western Australia near Augusta. The site has over 100 motifs engraved on a series of exposed limestone surfaces. While local residents have known about the site for over 30 years, the popular opinion was that the engravings were a series of fossil footprints. This view was reinforced by the discovery of a huge fossil egg in a coastal dune blow-out nearby. This egg, now in the Western Australian Museum, has been discussed by Merrilees (1979). It is probably from the now extinct *Aepyornis* native to Madagascar, clearly intrusive in the locality, and hence unrelated to the engraving site.

Location

The site, Western Australian Museum Department of Aboriginal Sites Registration Number S1786, is on privately owned land east of the town of Augusta. It is 3 km from the Southern Ocean and several hundred metres south of the Scott River (34°18′ S, 115°25′ E). Details of the land ownership and access are held by the Registrar of Aboriginal Sites who should be consulted prior to visiting the site.

Site Description

The engravings are in a cleared and fenced paddock, with an established pasture used for cattle grazing. There are a few scattered paperbark trees (*Melaleuca* sp.) remaining from the previously cleared native vegetation, and some *Agonis* sp. have regrown. Both these plants and the pasture species indicate that the site area was originally swamp. To the west there is well-vegetated sand dune with Jarrah *(Eucalyptus marginata)*-Marri *(E. calophylla)* woodland. To the south, a mixture of Peppermint (*Agonis flexuosa*) woodland and coastal

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heath occur, while to the north and east are extensive areas of heath land with minor stands of Jarrah-Marri woodland on sandy rises. *Agonis* and paperbark woodlands occur throughout the areas surrounding swamps and winter wet depressions.

A series of flat tabular limestone pavements occur in the north-west section of the cleared area. Engravings are on the more southerly of the pavements. They occupy an area of approximately 75 m north-to-south, 25 m wide, including about 25 limestone blocks. The limestone surface is level with the surrounding sandy soil, and in many cases pasture plants have grown over the limestone surface and obscure the engravings. The limestone slabs which make up the pavement are thin and tabular, ranging in size from less than 0.5 m to a maximum of 2.5 m across, with a thickness of between 50 mm and 100 mm. Some blocks have been broken and up-ended, possibly by land clearing or cultivation activity in the past. The area between blocks contains siliceous sandy soil, and the blocks are underlain by slightly clayey siliceous sands. The remainder of the paddock contains very loose siliceous sandy soils except for a small area of limestone outcrop around a disused well in a shallow depression near the centre of the paddock. This limestone has been heavily abraded by stock activity and no engravings were discovered. While the sandy soils appear to overlie the limestone, no evidence of the limestone could be found in ditches at the southern end of the paddock, or in a dam excavated in the north-east corner. However, there are several areas to the east of the paddock with limestone pavements made up of small discoidal limestone fragments. No stone artefacts were found in the soils surrounding the engravings.

The Engravings

Of the over 100 engravings at the site, animal tracks comprise the main motif. These tracks or footprints are fully engraved, and in many cases closely resemble actual animal tracks. However, they are usually somewhat larger than lifesize. There is no colour contrast between the engraved areas and the natural rock surface. Large bird tracks, presumably representing those of emus, are the most common. Other smaller bird tracks, perhaps representing bustard and unidentified wading types, are the next most numerous. There are a number of macropod tracks, including some with both hind and fore prints engraved. In addition to the tracks, there are a few other engravings including a star motif made by three lines crossing at a central point, single wandering lines (which may represent snake or lizard tracks), and several boomerang-shaped outlines. Several engravings have been truncated at the edge of a limestone block. In one case a track set can be linked to another on a nearby limestone block. Examples of the engravings are shown in Figure 1.

Local Geology

The occurrence of limestone on the Scott River plain is somewhat surprising because of the highly leached nature of the locality, and the extensive areas of white siliceous sand. The limestone which carries the engravings is cream-coloured when fresh, quite friable and soft. It is highly porous with a network of large interconnected pores between 2 mm and 4 mm diameter making up 50 per cent of the rock volume, and a smaller pore network

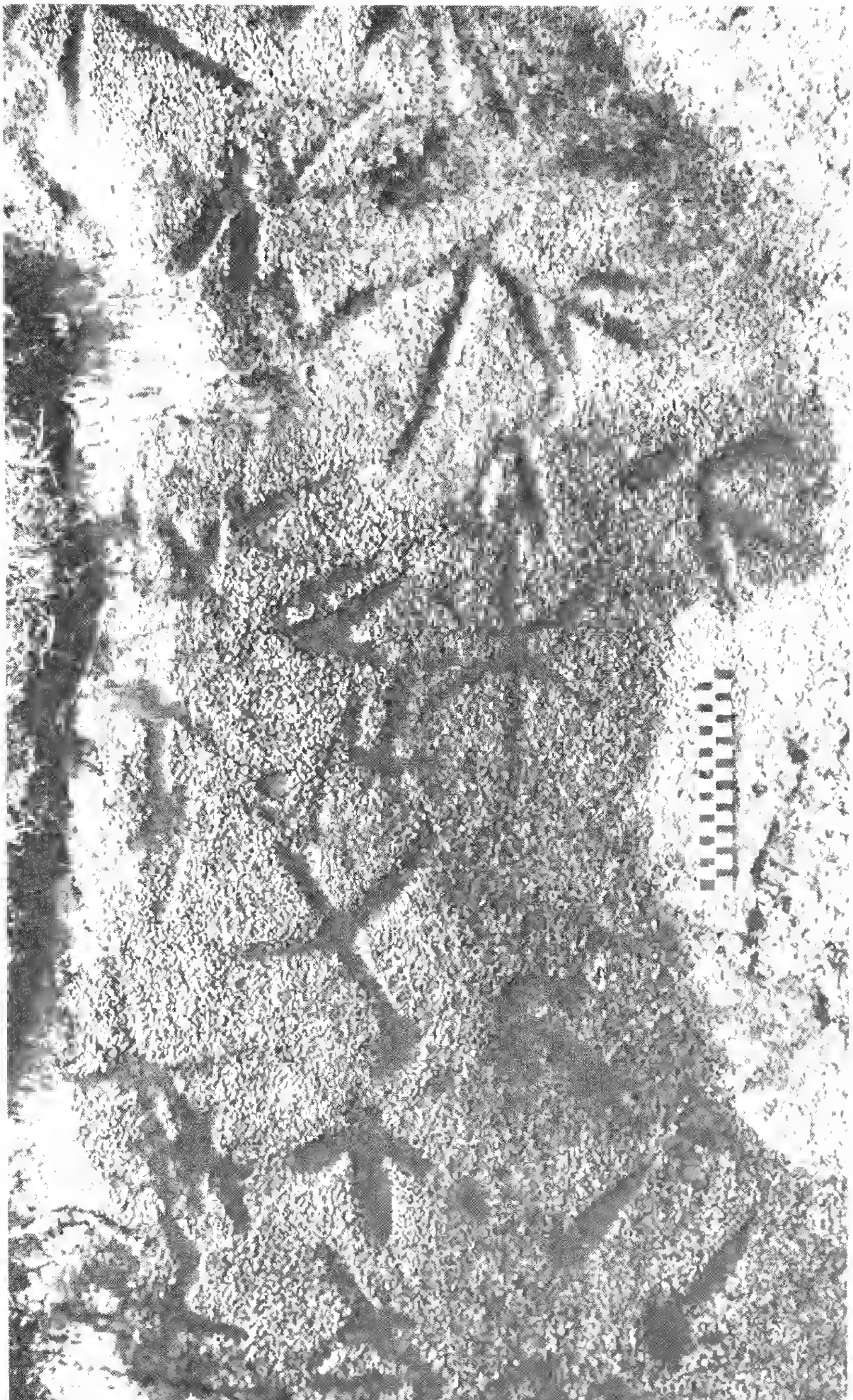

Figure 1 Rock engravings near Augusta, Western Australia. Water spread on surface to increase contrast. Photograph courtesy of A. Baynes.

in the 0.1 mm range spaced between the finely granular carbonate grains. The surface has developed a dense calcrete layer up to 3 mm thick, with most of the pore space infilled with secondary carbonate. The engraved areas also exhibit this surface calcrete layer or skin, but the thickness is unknown.

The rock composition is typical of so-called algal limestones. These are thought to form as a result of algal mats in shallow waters trapping carbonate material – either physically from dust and sediment input, or biologically from carbonate fixation by the algae as part of its metabolic process. This view is supported by the occurrence of the discoidal limestone pavement to the east of the site. These circular structures, ranging in size from 10 mm to 120 mm in diameter and up to 10 mm thick, are accepted as evidence of algal activity in shallow well-protected lakes. Modern examples exist in several of the interdunal lakes on the west coast south of Perth. These lakes often exhibit wide annual ranges in salinity, from brackish in winter to hyper-saline in summer.

Discussion

This site raises a number of interesting issues. It would appear to extend the known range of what has been called the 'Panaramitee Style' (Maynard 1979) to the extreme south-west corner of Western Australia. The nearest known sites of this style are at Yalgoo, 420 km north of Perth, and Yellerrie, 680 km north-east of Perth. There are only two other known rock engraving sites in the south of the state, one at Bolgart, 70 km north-east of Perth (Clarke 1976), and the other at Cape Arid on the south coast, east of Esperance. Both these sites are stylistically different and contain outline engravings around natural fractures and veins in the rock.

The Augusta site is also of geological interest. The rock was formed in a shallow lake, probably in an interdunal depression, at a time when there was a significant input of calcium carbonate. The thin nature of the carbonate indicates that the lake was short-lived in a geological sense. A Pleistocene date is indicated by surrounding deposits. However, the main question is how did the rock survive in an area which has a high rain fall, and in which surrounding soils are strongly leached? Even more perplexing is how the engravings survived in such an environment, when based on stylistic criteria they should be of considerable age. Burial by dune activity and then re-exposure at some later date would appear to be the most likely possibility. It is inconceivable that an engraving in an exposed limestone as porous and friable as this, could have survived over any extended time without protection. Weathering rates for exposed limestone without substantial soil cover is in the order of several millimetres per 100 years. If only a thin layer of soil and vegetation cover the rock surface, allowing the downward movement of humic acids, the weathering rate increases up to 10 times (Ingle-Smith 1978). A detailed study of the site geomorphology and further geological investigations are needed to establish a more precise site history. In turn, this may shed light on the possible age of the engravings, particularly if they have undergone a period of burial.

Finally, there remains the problem of site preservation in light of the present environmental conditions. Every effort should be made to keep vegetation off the engraved limestone to prevent accelerated weathering by biological activity. The site should be fenced so that physical damage by cattle or farm machinery is prevented. In the longer term, consideration needs to be given to impregnating the rock to help prevent solution weathering and to assist the shedding of water from the rock surface. The alternative would be to lift the slabs and place them in a covered storage area, or to roof the site, neither of which are practically or aesthetically pleasing. However, without appropriate conservation and preservation action, this important site will be lost.

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SHORT COMMUNICATIONS

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Additions to the Vertebrate Fauna of Bendering Nature Reserve

John Dell*

The survey of Bendering Nature Reserve formed part of the biological survey of the Western Australian Wheat Belt (Kitchener 1976). Data on the vertebrates of the reserve were published (Kitchener *et al.* 1977) and the methodology for surveying vegetation and floristics was developed on this reserve (Muir 1977). The vertebrate survey was conducted in November 1972 and March 1973 prior to the major work of Muir and before the construction of firebreaks in and around the reserve. An examination of the Bendering vertebrate data subsequent to the submission of the manuscript and a comparison with other reserves sampled in the Wheat Belt suggested that the assemblage of birds and reptiles at Bendering was incomplete. This was presumably a consequence of timing of the survey when many non-resident species may have been overlooked and a lack of access to the heterogeneous northern part of the reserve which was illustrated by Muir.

As data on species richness and habitat preferences of Wheat Belt vertebrates was to be analysed, it became necessary to re-examine Bendering Nature Reserve to complete the list of vertebrates. Further work on 8-9 December 1977 and 1-2 October 1979 added 4 reptile species and 16 bird species. The total number of species but not the individual data have been used by Kitchener *et al.* (1980, 1982), Kitchener (1982) and Humphreys and Kitchener (1982). Data on additional species are listed below with habitat indicated by vegetation location numbers which are directly referable to Muir 1977.

New Birds

Mountain Duck *(Tadorna tadornoides)* 2 over loc. 1.1 at night; Black Duck *(Anas superciliosa)* 1 in swamp near loc. 1.9 (Muir pers. comm.); Wood Duck *(Chenonetta jubata)* 2 at dam on edge of reserve; Brown Goshawk *(Accipiter fasciatus)* 1 in loc. 4.17; Collared Sparrowhawk *(Accipiter cirrocephalus)* 1 in loc. 3.14; Bush Stone-curlew *(Burhinus grallarius)* 1 calling near loc. 1.1 at night; Crested Pigeon *(Ocyphaps lophotes)* 1 in loc. 2.164 and others in road verges; Tawny Frogmouth *(Podargus strigoides)* 1 in loc. 3.24; Horsfield's Bronze Cuckoo *(Chrysococcyx basalis)* 1 in loc. 4.16; Rufous Whistler *(Pachycepahala rufiventris)* 1 in loc. 2.34; Grey Fantail *(Rhipidura fuliginosa)* 1 in loc. 2.2; Western Flyeater *(Gerygone fusca)* 1 in loc. 2.84; Chestnut-rumped Thornbill *(Acanthiza uropygialis)* 1 in loc. 1.1; White-fronted Honeyeater *(Phylidonyris albifrons)* 2 in loc. 3.10; Magpie-lark *(Grallina cyanoleuca)* 1 at dam on reserve boundary; Little Crow *(Corvus bennetti)* 1 over loc. 4.16.

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New Reptiles

Diplodactylus pulcher 1 in ecotone between loc. 1.9 and 2.34; *Delma australis* 1 in each of loc. 1.8, 2.50 and breakaway near loc. 1.12; *Delma fraseri* 2 in loc. 2.50 and 1 in loc. 2.72; *Menetia greyii* 1 in loc. 1.1.

Further breeding data collected on 1-2 October 1979 on species previously known from the reserve are: *Crenadactylus ocellatus* — 3 females with 1 egg in each oviduct; *Diplodactylus granariensis* — 3 females with 1 egg in each oviduct, *D. maini* — 1 female with 1 egg in each oviduct; *D. spinigerus* — 1 female with 1 egg in each oviduct; *Ctenophorus maculatus griseus* — 1 female with 2 eggs in each oviduct; *Cryptoblepharus plagiocephalus* — 1 female with one egg in each oviduct; *Ctenotus pantherinus* — 1 female with 3 eggs in each oviduct. Males of *D. granariensis, D. pulcher, Gehyra variegata, Ctenophorus cristatus, C. maculatus griseus, Cryptoblepharus plagiocephalus, Ctenotus schomburgkii* and *Morethia obscura* had enlarged testes in October. Twenty-three reptile species are now recorded from Bendering Nature Reserve and reproductive data are available for 16 species.

A total of 71 species of birds are now recorded for Bendering Nature Reserve and the adjacent farmland; this is little different from the 73 species recorded from the nearby West Bendering Nature Reserve (Dell 1977). The October survey coincided with prolific flowering of several eucalypt and other myrtaceous and proteaceous shrubs; accordingly nectar-seeking birds such as Brown Honeyeater *(Lichmera indistincta)*, Singing Honeyeater *(Meliphaga virescens)*, Tawny-crowned Honeyeater *(Phylidonyris melanops)* and Red Wattlebird *(Anthochaera carunculata)* were more common than previously recorded. Red Wattlebird was breeding, one nest had 2 fresh eggs and another had a young bird nearly fledged.

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Habitats of the Heart Urchins *Protenaster* and *Rhynobrissus*

K.J. McNamara* and C. Bryce†

Accurate published quantitative data on the depth of burial and substratum preferences of living heart urchins are, as Smith (1980: 43) has noted, sadly lacking; they are recorded for only 13 heart urchin genera (Smith 1980). The only information recorded on *Protenaster* is that is has been collected from a depth of 6 fathoms (Hall 1904). Our knowledge of the habitat of *Rhynobrissus* is only marginally better. Clark (1917) recorded that specimens were collected from between 23 and 39 fathoms. Mortensen (1951) noted that *R. hemiasteroides* Agassiz, 1879 is a littoral species which lives to a depth of at least 75 m. McNamara (1982) noted the presence of calcareous sand, 0.1-1.0 mm in diameter, within the gut of *R. tumulus* McNamara, 1982. During early 1983 living specimens of *Protenaster australis* (Gray, 1857) and *Rhynobrissus hemiasteroides* Agassiz, 1879 were collected by C.B. Two specimens of each were discovered living buried in sand. The aim of this short note is to provide details of the habitats of these species, principally water depth, depth of burial in the sediment and the sediment grain size and composition.

Protenaster australis (Gray, 1857)

Two specimens, WAM 740.83 and 741.83 (test lengths 90 mm and 77 mm respectively), were collected off Trigg Beach, Western Australia. They were found living in sand in a pocket in the limestone reef platform. The sediment/water interface was about 1.5 m below the surface of the reef platform and at a water depth of about 1.8 m. The sand pocket was connected to the open sea via channels within the reef. It was located about 30 m from the shore. Within the sand, the echinoids were buried to a depth of about 10 cm. The location of each echinoid was marked by the presence of a slightly raised, darker patch of disturbed sand that was about twice the area of each animal. We consider it likely that the echinoids were connected to the surface by a mucus-lined funnel although we have not observed this directly. On exposing the echinoids and leaving them on the sediment surface, they proceeded to burrow, the anterior of the test descending more rapidly than the posterior, initially. The echinoids completely covered themselves with sand within 15-20 minutes.

The sand in which the echinoids were buried is a fine-grained calcareous sand. The sediment grain size ranged from about 0.02 mm up to 1.3 mm. However, the diameter of most grains lay in the range of 0.125 to 0.25 mm (see Table 1 for grain-size analysis). The grains have been poorly rounded; sphericity of the grains is generally low. A proportion of the sand consists of unworn foraminifers, sponge spicules, broken bryozoan fragments, complete small bivalves and echinoid spines. The major part of the sand, however, consists of worn molluscan fragments.

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Rhynobrissus hemiasteroides Agassiz, 1879

Two specimens, WAM 742.83 and 743.83 (test lengths 38.5 mm and 33 mm respectively) were collected off White Tops Reef, Port Denison, Western Australia. They occurred at a water depth of 10 m, buried in sand on the exposed, south-westerly side of the reef. The sand surface was strongly current rippled. The echinoid's presence, as with *P. australis,* was indicated by a disturbed area on the substratum which was darker in colour than the surrounding sand. Both specimens were covered by about a 10 cm thickness of sand. When uncovered they would immediately begin to bury themselves with a forward, sinking motion. Complete coverage was accomplished in only 20-30 seconds.

The sand is predominantly calcareous, although it does contain a minor proportion of quartz and lithic fragments. The sand grains range in diameter from about 0.05 to 2 mm, although the majority of grains are in the range of 0.125 mm to 0.5 mm (see Table 1 for grain-size analysis). Compared with the nature of the sand in which *P. australis* was discovered, the sand inhabited by *R. hemiasteroides* is more mature, the grains being more rounded, and displaying a higher degree of sphericity and larger grain size. Identifiable components include bryozoans, sponge spicules and foraminifers.

Table 1 Sediment grain-size analysis.

Grain size (in mm)	**<0.063**	**>0.063**	**>0.125**	**>0.25**	**>0.5**	**>1.0**
P. australis sand	<0.5%	6.9%	74.5%	17.5%	0.9%	<0.5%
R. hemiasteroides sand	trace	2.3%	47.5%	42.5%	5.7%	1.6%

Discussion

Smith (1980) attempted to correlate aboral tubercle density with sediment grain size. He noted how, particularly in spatangoids, inhabitants of finer grained sediments possess a greater number of tubercles per mm^2. *Rhynobrissus,* with about 10 tubercles/mm^2 and inhabiting fine sand, compares with *Echinocardium* (Smith 1980, Fig. 109) and fits the general trend which Smith observed. However, *Protenaster,* found inhabiting an even finer-grained sand than *Rhynobrissus,* has, at a comparable size to *Rhynobrissus,* a density of only 3 tubercles/mm^2. Thus although the trend observed by Smith may be valid in a very general sense, *Protenaster* forms an exception. Presumably factors other than sediment grain size are also influencing the density of aboral tuberculation.

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Occurrence in Australia of the Centipede Genus *Asanada* Meinert (Chilopoda, Scolopendridae, Scolopendrinae)

L.E. Koch*

A specimen from Line Hill, Queensland, in the collection of the Queensland Museum has been determined as *Asanada brevicornis* Meinert, 1886. The specimen fits the description and illustrations given by Attems (1930). This appears to constitute the first record of the genus in Australia. Line Hill (12°45'S, 143°21'E) is in the Iron Range of north-eastern Queensland, and the specimen (Reg. No. QM S1317) was collected by Drs Valerie Davies and Robert Raven during 4-7 July 1976.

The genus *Asanada* Meinert, 1886, comprised four species according to Attems (1930); and Würmli (1972) and Lewis (1973) have described a few more. The genus was previously known from South and North Africa (including Guinea, Nigeria, Congo, Sudan, Eritrea, Palestine, and Socotra), India (Himalayas), Burma, Andaman Is, Philippines, Sumba, and New Guinea.

Asanada brevicornis is the type species of the genus. In order to clarify the present determination it is pointed out that Attems (1930) synonymized *A. brevicornis* var. *afra* Silvestri, 1918, as *A. socotrana* Pocock, 1899, and regarded South African forms identified as *A. brevicornis* by Attems (1928) as belonging to this species. However, Lawrence (1955) regarded all these as belonging to the subspecies *A. socotrana kalaharina* Lawrence, 1936; whereas Lewis (1967, but not in some later papers) treats them as *A. socotrana attemsi* Lewis, 1967. *A. brevicornis* is therefore not recognized from Africa; the distribution of this species thus includes India, Burma, Andaman Is, New Guinea, and now Australia.

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Guide to Authors

Subject Matter

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. Full length papers should not normally exceed 30 typed pages. 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.

Presentation

Authors are advised to follow the layout and style in the most recent issue of the *Rec. West. Aust. Mus.* including headings, tables, illustrations and references.

The title should be concise, informative and contain key words necessary for retrieval by modern searching techniques. Names of new taxa must not be included. An abridged title (not exceeding 50 letter spaces) should be included for use as a running head.

An abstract must be given in full length papers but not short communications, summarizing the scope of the work and principal findings. It should normally not exceed 2% of the paper and should be suitable for reprinting in reference periodicals. Contrary to Recommendation 23 of the International Code of Zoological Nomenclature it may include names of new taxa.

Footnotes are to be avoided, except in papers dealing with historical subjects.

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*.

Systematic papers must conform with the International Codes of Botanical and Zoological Nomenclature and, as far as possible, with their recommendations.

Synonymics should be given in the short form (taxon, author, date, page) and the full reference cited at the end of the paper.

Manuscripts

The original and two copies of manuscripts and figures should be submitted to the Editorial Committee, 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 headings and legends to illustrations should be typed on separate pages. The desired positions 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.

High quality illustrations are required to size (13.5 cm x 18 cm) or no larger than 32 cm x 40 cm with sans serif lettering suitable for reduction to size. Photographs must be good quality black and white prints, 13 cm x 18 cm (5 inches x 7 inches). If scale line and lettering are required on photographs *do not* place directly on to print. They should be positioned on a clear paper or film overlay. Scale must be indicated on illustrations. All maps, line drawings, photographs and graphs, should be numbered in sequence and referred to as Figure/s in the text and captions. Each must have a brief, fully explanatory caption.

In papers dealing with historical subjects references may be cited as footnotes. In all other papers references must be cited in the text by author and date and all must be listed alphabetically at the end of the paper. The names of journals are abbreviated according to *World List of Scientific Periodicals*. The use of 'unpublished data' or 'personal communication' is discouraged.

Processing

Papers and short communications are reviewed by at least two referees and acceptance or rejection is then decided by an editorial committee.

The senior author is sent two sets of galley proofs (one to be retained) and one set of page proofs which must be returned promptly.

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RECORDS of the Western Australian Museum

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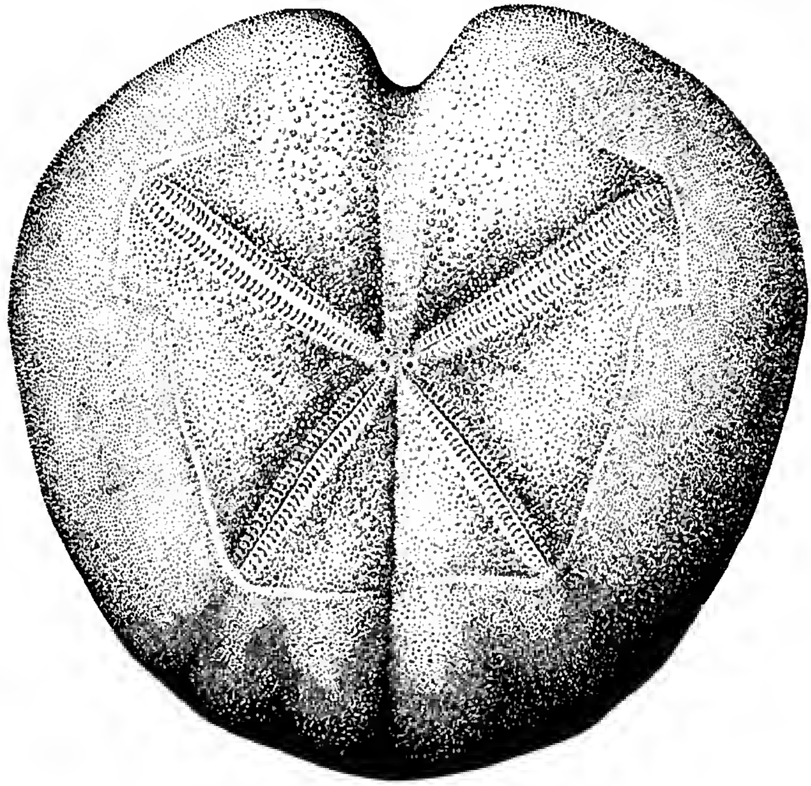

Rec. West. Aust. Mus. 1984, 11 (2): 77-86

A New Genus of Mite (Acari: Acaridae) Phoretic on Bees (*Ctenocolletes*) in Australia

A. Fain*

Abstract

A new genus, *Ctenocolletacarus,* and three new species, *C. longirostris, C. grandior* and *C. brevirostris,* are described from hypopial nymphs from three species of bees (*Ctenocolletes,* Stenotritidae) from Western Australia.

Introduction

The new mites described herein are known only from hypopial nymphs obtained by T.F. Houston, Western Australian Museum, Perth (WAM), from adult bees (*Ctenocolletes,* Stenotritidae). Most were secreted in the abdominal tergal pouches of females, but some occurred under the edges of the abdominal terga and on other parts of the bodies of male and female bees (Houston in press).

The holotypes of the new species are deposited in the WAM. Paratypes are also deposited there, in the Institut royal des Sciences naturelles de Belgique, Bruxelles (IRSNB) and in the British Museum (Natural History), London (BMNH).

The host bees are in the WAM and the Western Australian Department of Agriculture, Perth (WADA).

Systematics

Acari: Acaridae

Genus *Ctenocolletacarus* gen. nov.

Type Species

Ctenocolletacarus longirostris sp. nov.

Diagnosis

With characters of hypopial nymphs of the Acaridae, but differing from all other genera of this family by prolongation of antero-dorsal extremity of idiosoma into a well-developed rostrum. Resembling *Caloglyphus* Berlese, 1923 (= ?*Sancassania* Oudemans, 1916) and *Lackerbaueria* Zachvatkin, 1941 but differing by presence of a rostrum, its longer sternum (together with epimeres II)

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almost reaching coxae III and its transversely striated dorsal shields. Differing from *Lackerbaueria* in coxal fields III being separated medially (fused in *Lackerbaueria*). Resembling *Paraceroglyphus* Fain and Beaucournu, 1973 in epimeres III-IV forming closed coxal fields (narrowly separated medially) but differing in presence of rostrum, longer sternum, presence of 5 foliate setae on tarsi IV and one saucer-like seta on tarsi I-II.

Description

Body oval. Dorsal surface slightly convex. Sejugal furrow strong, well forward. Dorsum of body almost completely punctate. Dorsal setae short, either thin or spinous, except long piliform *ℓ 5*. Oil glands opening between setae *h* and *ℓ* 2. Venter: Palposoma completely covered by rostrum, longer than wide, with anterior margin slightly incised, bearing two solenidia α and two pairs of short lateral setae. Sternum loosely connected posteriorly with epimeres II. Two narrow paramedian poorly sclerotized pregenital sclerites present. Suctorial plate large, wider than long. Anterior suckers distinctly smaller than posterior suckers; conoids approximately on same line as posterior suckers (Fain 1973). Legs rather short and thick, ending in a well-developed curved claw.

Chaetotaxy of body: Setae *v i* spinose; *v e* short, thinner than *v i*; *s cx* very thin. Other setae present: *d 1* to *d 5*, *ℓ 1* to *ℓ 5*; *h*; *s h*; *g a*; *g m*; *g p*. Setae *cx I*, *cx III* and *g p* modified into conoids (Fain 1973).

Legs: tarsi I-II with 1 long simple seta and 2 short setae (one thin and one spine-like). Tarsi III with 7 foliate and 1 piliform setae. Tarsi IV with 5 foliate and 3 unequal piliform setae (1 very long, 1 long and 1 short). Tibiae I-II with 2-2-1-1 setae. Genua 2-2-1-0. Femora 1-1-0-1. Trochanters 1-1-1-0. Solenidia: Tarsus I with $\omega\ 1$ slightly dilated; $\omega\ 3$ slightly pore apical and tapering at apex: $\omega\ 2$ cylindrical, more basal. Tibiae I-IV with a well-developed solenidion.

Key to Species of *Ctenocolletacarus*

1	Idiosoma prolonged anteriorly by a short rostrum. Most of dorsal setae spinose. Dorsal striations forming a network	*C. brevirostris* sp. nov.
	Idiosoma prolonged anteriorly by a long rostrum. Dorsal setae thin, piliform. Dorsal striations not forming a network	2
2	Rostrum long and narrow. Posterior suckers slightly wider (18-19 µm) than anterior suckers (13-15 µm). Idiosoma 340-426 µm long	*C. longirostris* sp. nov.
	Rostrum relatively shorter and thicker. Posterior suckers almost twice as wide (33-36 µm) as anterior suckers (18-20 µm). Idiosoma 548-585 µm long	*C. grandior* sp. nov.

Ctenocolletacarus longirostris sp. nov.

Figures 1-6, 10

Holotype

WAM 83/169, hypopus on slide, ex tergal pouches of *Ctenocolletes nicholsoni* ♀; 200 km N of Geraldton, Western Australia, 20.viii.1971, T.F. Houston.

Paratypes

Western Australia

Ctenocolletes centralis: 50 hypopi ex tergal pouches of ♀ (WAM 82/1890), 12.5 km ENE of Anketell HS (28°02'S, 118°51'E), 6-7.ix.1981, T.F. Houston (WAM 32 hypopi, WAM 83/360-2; IRSNB 10 hypopi; BMNH 8 hypopi); 12 hypopi from various parts of body of ♂♂ (WAM 82/1893, WADA TFH R15), 4.8 km S of Neale Junction (28°18'S, 125°49'E), 16.vii.1974, K.T. Richards (WAM 8 hypopi, WAM 83; IRSNB 2 hypopi; BMNH 2 hypopi).

Ctenocolletes nicholsoni: 35 hypopi, same data as for holotype (WAM 27 hypopi, WAM 83/363-8; IRSNB 8 hypopi); 13 hypopi from ♀, 16 km S of Nerren Nerren HS (27°08'S, 114°38'E), 19.viii.1980, C.A. Howard and T.F. Houston 329-1 (WAM 8 hypopi, WAM 83/379-82; IRSNB 5 hypopi); 40 hypopi ex tergal pouches of ♀ (WAM 82/1881), 37 km NE of Laverton, 10-12.ix.1982, B. Hanich and T.F. Houston (WAM 32 hypopi, WAM 83/369-73; IRSNB 6 hypopi; BMNH 2 hypopi).

Diagnosis

Distinguished from the two other species of the genus by the long, narrow shape of the rostrum.

Description

Holotype 412 μm long (including rostrum), 249 μm wide (maximum width). Measurements in 8 paratypes (in μm): 426 x 246; 420 x 248; 395 x 240; 390 x 240; 380 x 242; 368 x 213; 350 x 210; 340 x 210. Specimens measuring less than 380 μm are less frequent than those exceeding this length. These small specimens correspond closely to the larger ones except for size of body and of some organs (setae, suckers, etc.). Dorsum: Rostrum 80 μm long and 27 μm wide in its middle. Cuticle covering the rostrum raised to form a crest. Setae *v i* are thick spines, *v e* are smaller and thinner spines. All dorsal setae thin and short except *ℓ 5* 125 μm long. Venter: Palposoma 30 μm long, 19 μm wide; α 28-30 μm long. Sternum 87 μm long. Pregenital sclerites fused anteriorly with epimeres IV. Suctorial plate 94 μm wide; anterior suckers 13-15 μm wide, posterior suckers 18-19 μm wide; they are preceded by a flat rounded area. Legs relatively thick and short. Length of tarsi I-IV (in μm): 24-24-27-27. Chaetotaxy of legs I-IV: Tarsi I-II with 2 simple setae (one of 50 μm and one of 12-15 μm) and one spinous seta.

Ctenocolletacarus grandior sp. nov.

Figures 8-9

Holotype

WAM 83/170, hypopus on slide, ex tergal pouches of *Ctenocolletes centralis* ♀ (WAM 82/1890); 12.5 km ENE of Anketell HS (28°02'S, 118°51'E), Western Australia, 6-7.ix.1981, T.F. Houston.

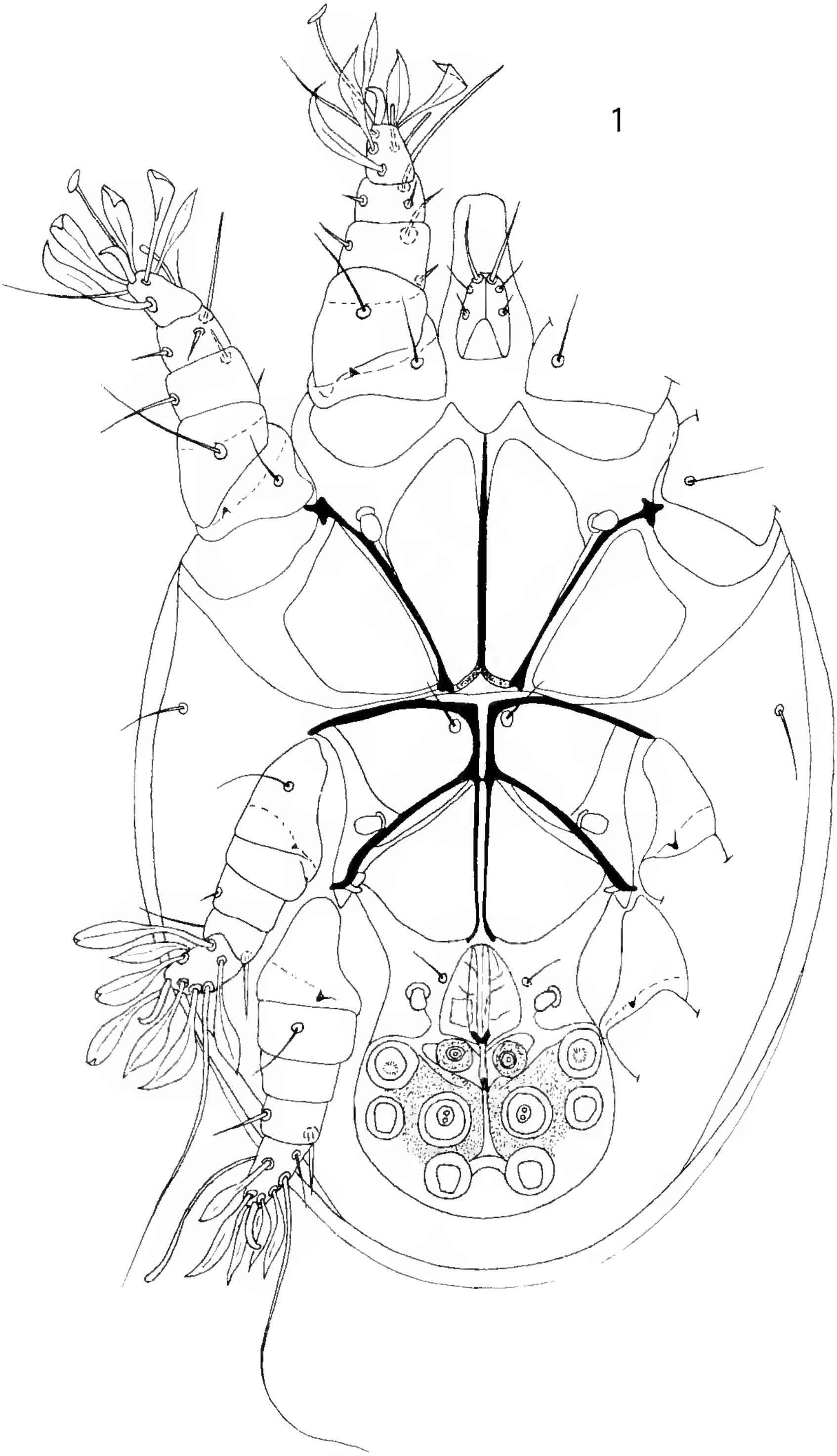
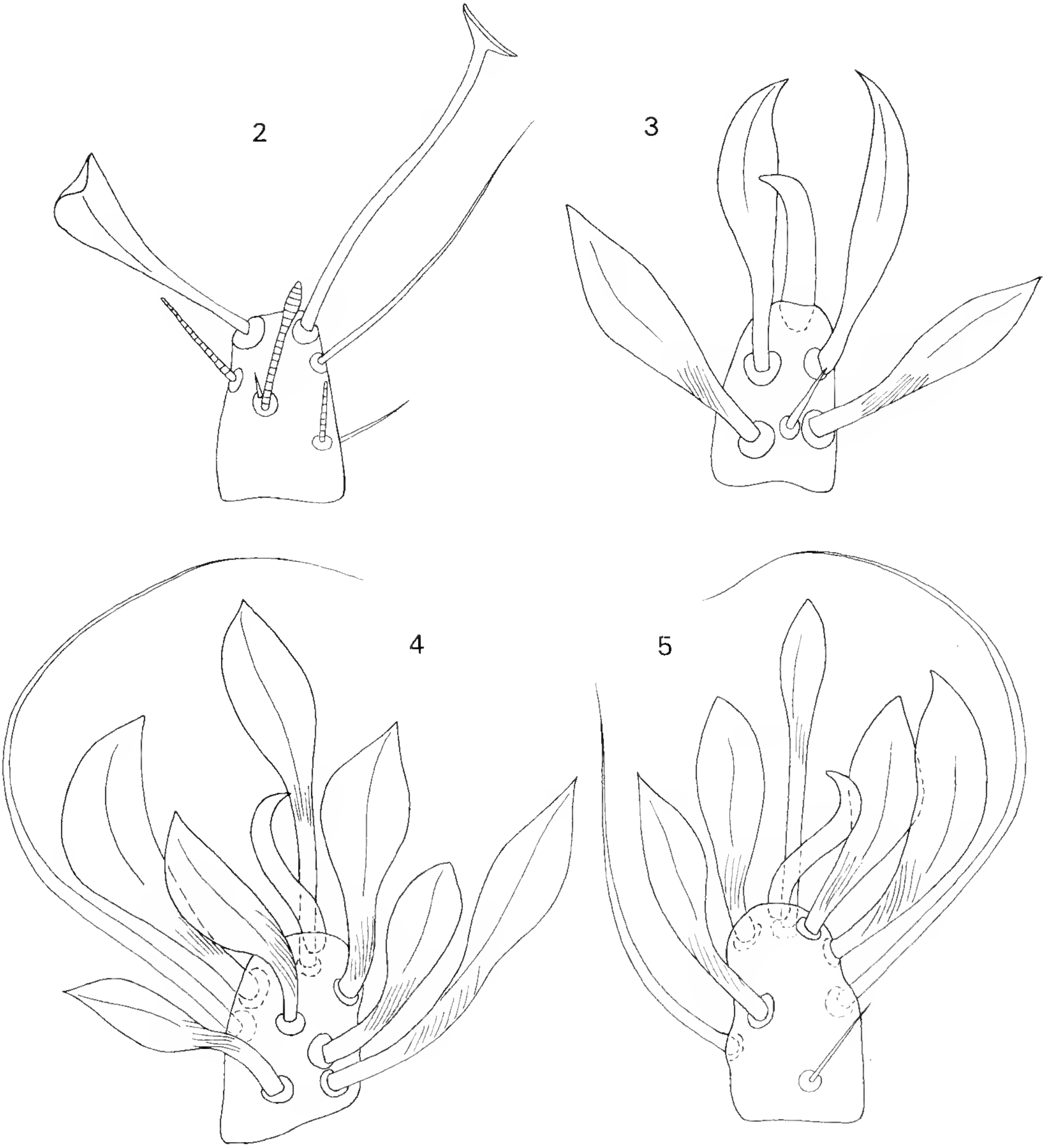


Figure 1 *Ctenocolletacarus longirostris* sp. nov. Hypopus in ventral view.



Figures 2-5 *Ctenocolletacarus longirostris* sp. nov. Hypopus. Tarsus I in dorsal view (2) and ventral view (3). Tarsi III (4) and IV (5) in lateral view.

Paratypes

Western Australia

Ctenocolletes centralis: 11 hypopi from various parts of body of ♂ (WAM 82/1893); 4.8 km S of Neale Junction (28°18′S, 125°49′E), 16.vii.1974, K.T. Richards (WAM 6 hypopi, WAM 83/357-9; IRSNB 3 hypopi; BMNH 2 hypopi).

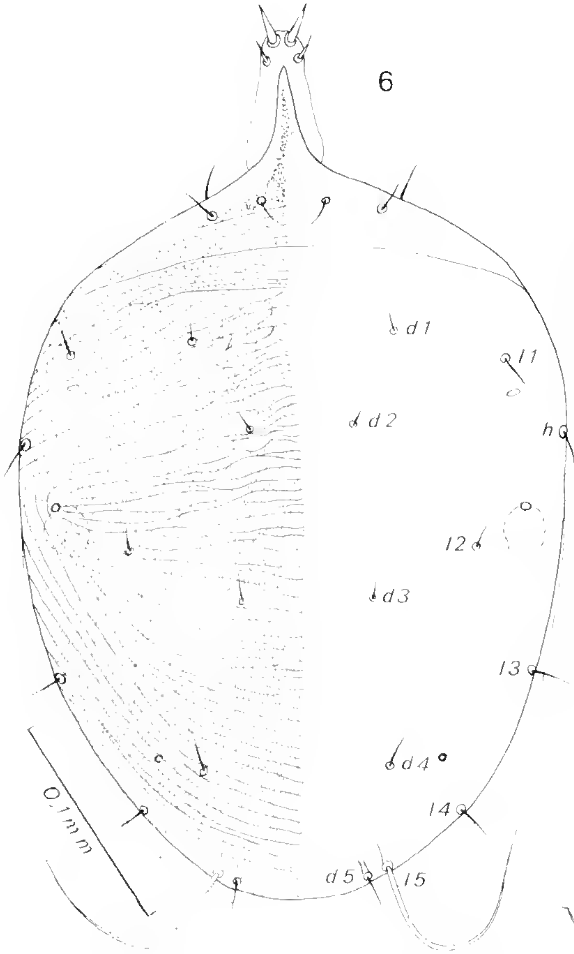
Ctenocolletes nicholsoni: 1 hypopus from ♀; 16 km S of Nerren Nerren HS (27°08'S, 114°38'E), 19.viii.1980, C.A. Howard and T.F. Houston 329-1 (WAM 83/356).

Diagnosis

Distinguished from *C. longirostris* by the relatively wider and shorter rostrum, the much larger idiosoma and the relatively larger posterior suckers.

Description

Holotype 550 μm long (including rostrum), 345 μm wide. In 7 paratypes, measurements (in μm): 585 x 375; 572 x 360; 570 x 365; 569 x 350; 560 x 360; 555 x 345; 548 x 325 (the smallest specimen of the collection). Postero-lateral margins of idiosoma membranous. Dorsum as in *C. longirostris.* Rostrum relatively shorter but wider in its posterior half than in that species. Ventral surface



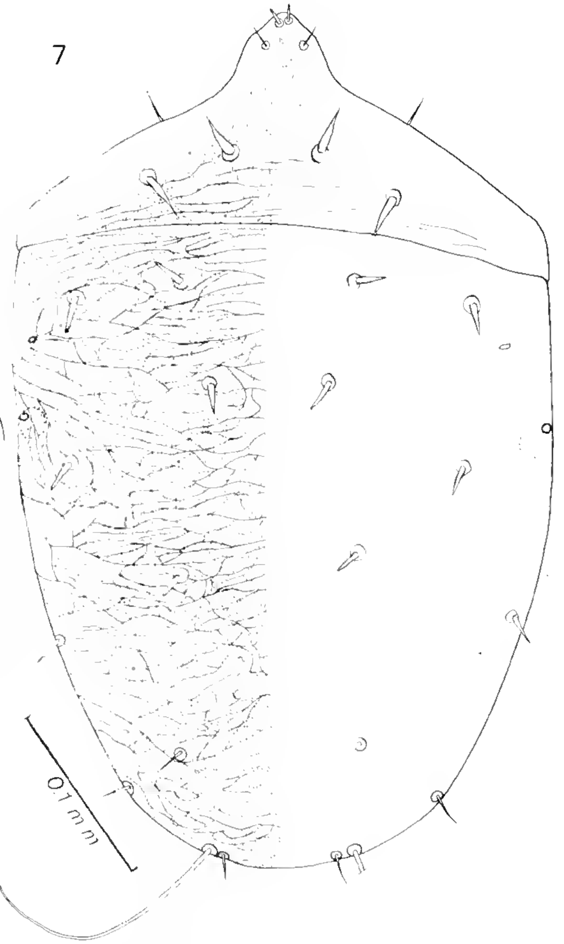
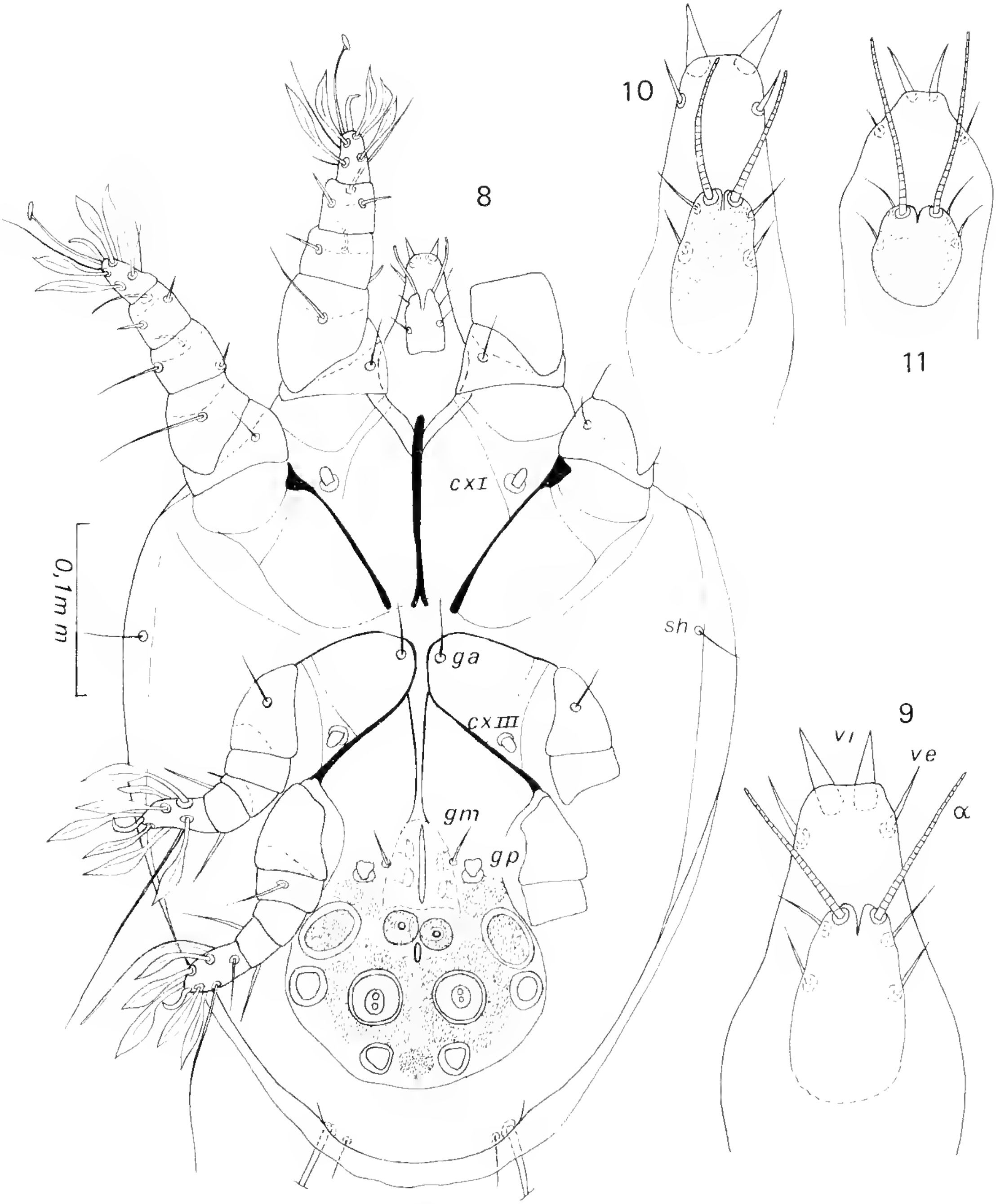


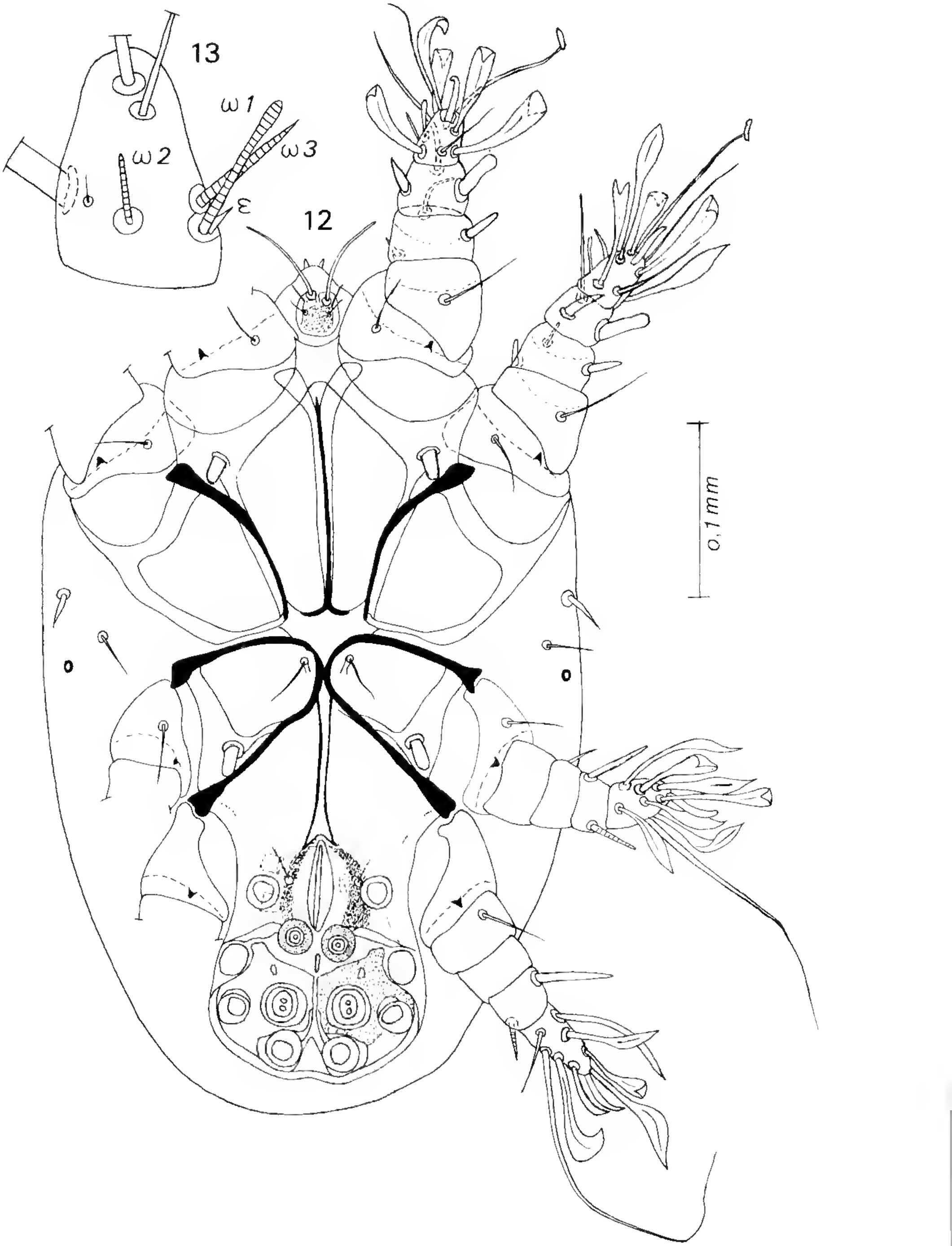
Figure 6 *Ctenocolletacarus longirostris* sp. nov. Hypopus in dorsal view.
Figure 7 *Ctenocolletacarus brevirostris* sp. nov. Hypopus in dorsal view.



Figures 8-9 *Ctenocolletacarus grandior* sp. nov. Hypopus in ventral view (8). Rostrum and palposoma in ventral view (9).

Figure 10 *Ctenocolletacarus longirostris* sp. nov. Hypopus. Rostrum and palposoma in ventral view.

Figure 11 *Ctenocolletacarus brevirostris* sp. nov. Hypopus. Rostrum and palposoma in ventral view.



Figures 12-13 *Ctenocolletacarus brevirostris* sp. nov. Hypopus in ventral view (12). Tarsus I in dorsal view (13).

as in *C. longirostris* except the suctorial plate which is relatively much larger (width 155 μm) and bears much larger suckers. Anterior suckers 18-20 μm wide, posterior suckers 33-36 μm wide (exceptionally 38 μm). Lateral conoids slightly more anterior than posterior ones and preceded by large oval flat area. Legs longer than in *C. longirostris*; length of tarsi (in μm): 31-31-33-33.

Ctenocolletacarus brevirostris sp. nov.

Figures 7, 11-13

Holotype

WAM 83/171, hypopus on slide, ex tergal pouches of *Ctenocolletes albomarginatus* ♀ (WAM 47/1232); Merredin, Western Australia, presumably in 1947, A.M. Douglas.

Paratypes

Western Australia

Ctenocolletes albomarginatus: 20 hypopi, same data as for holotype (WAM 16 hypopi, WAM 83/353-5; IRSNB 4 hypopi); 38 hypopi ex tergal pouches of ♀ (WAM 82/1879); 37 km NE of Laverton (28°21'S, 122°37'E), 10-12.ix.1982, B. Hanich and T.F. Houston (WAM 29 hypopi, WAM 83/350-2; IRSNB 5 hypopi; BMNH 4 hypopi); 9 hypopi from body of ♂ (WAM 82/122), 21 km N of Geraldton, 19.viii.1971, T.F. Houston (WAM 5 hypopi, WAM 83/348-9; IRSNB 2 hypopi; BMNH 2 hypopi).

Diagnosis

Differs from the two other species in the genus by the much shorter rostrum, the spinose dorsal chaetotaxy and the network formed by the dorsal striation.

Description

Holotype 450 μm long, 240 μm wide. In 8 paratypes (in μm): 460 x 265 (largest specimen); 435 x 250; 423 x 237; 405 x 238; 390 x 240; 363 x 225; 340 x 220; 300 x 180 (smallest specimen). Posterior margin of body with very narrow membrane. Dorsum as in *C. longirostris* but transverse lines are connected to each other and form an irregular network. Dorsal setae are short thick spines, *sc i* situated distinctly in front of *sc e*. Rostrum short and with rounded apex, bearing small *v i* setae. Venter: Palposoma slightly longer than wide. Epimeres and suctorial plate as in *C. longirostris*, the plate is 93 μm wide, anterior suckers 15 μm, wide, posterior suckers 21 μm wide. Lateral conoids either on the same line as posterior suckers or slightly behind this line. Legs thicker than in *C. longirostris* and bearing much thicker spines on tibiae I-IV and on genua I-II. Tarsi I-IV 29-29-30 and 30 μm long.

Discussion

The material examined was obtained from a relatively small number of host specimens: *C. longirostris* from 3 specimens each of *Ctenocolletes centralis* and

C. nicholsoni; *C. grandior* from 2 *Ctenocolletes centralis* and 1 *C. nicholsoni*; and *C. brevirostris* from 3 *Ctenocolletes albomarginatus*. However, on the basis of these records it appears that *C. longirostris* and *C. grandior* share (and are confined to) two bee hosts (*Ctenocolletes centralis* and *C. nicholsoni*) while *C. brevirostris* is confined to a third (*C. albomarginatus*). This situation reflects the affinities of the host bees where *centralis* and *nicholsoni* are very closely related to each other and more distantly related to *albomarginatus* (Houston 1983).

Acknowledgements

I am grateful to Dr T.F. Houston for his constructive criticism of a draft of this paper.

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Living Australian Species of the Echinoid *Pericosmus* (Spatangoida: Pericosmidae)

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Abstract

Three species of *Pericosmus* are described from Australian waters. *P. porphyrocardius* sp. nov. is described on the basis of a suite of specimens from the North-West Shelf and one specimen from north-east Queensland. The two other described species are each only known from single specimens and are placed in open nomenclature. Both were collected from waters off the Queensland coast. The phylogenetic significance of the variability of the adoral plating in *P. porphyrocardius* is discussed.

Introduction

The spatangoid echinoid *Pericosmus,* which ranges from the Paleocene to Recent, occurs quite commonly in the Oligocene-Miocene rocks of southern Australia (McNamara and Philip [in press]). Hitherto, the record of extant species of *Pericosmus* living in Australian waters was confined to a single specimen collected on the Great Barrier Reef Expedition in 1928-1929 from near Lizard Island, and described by H.L. Clark (1932) as *Pericosmus macronesicus* Koehler, 1914.

Although nine living species of *Pericosmus* have been described, *Pericosmus* is not a common heart urchin. Of these nine species, seven (*P. macronesicus*; *P. cordatus* Mortensen, 1950; *P. bidens* Mortensen, 1950; *P. tenuis* Mortensen, 1950; *P. keiensis* Mortensen, 1950; *P. mauritianus* Mortensen, 1950; and *P. oblongus* Mortensen, 1950) are each based on only three specimens or fewer. Furthermore, some of these species are based on just one juvenile specimen. Of the two remaining species, *P. melanostomus* Mortensen, 1948 is based on a number of juvenile specimens, while *P. akabanus* Mortensen, 1939 is the only species to have been described on the basis of an appreciable number of adult specimens.

Although *Pericosmus* is not a common echinoid, it is a widespread, Indo-West Pacific genus. However, ranges of individual species are restricted. The paucity of specimens of each species probably largely reflects the lack of collections made from depths at which species of *Pericosmus* are known to occur. Mortensen (1951) records the genus as generally inhabiting depths between 200 and nearly 500 m, although *P. melanostomus* is said to have been collected from water as shallow as 18 m.

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In 1982, during trawling by the CSIRO vessel *Soela* on the North-West Shelf, 16 specimens of a large, purple heart urchin were collected from about 200-230 km NNW of Port Hedland. Further trawling by F.V. *Courageous* in the same area in 1983 yielded many hundreds of specimens. Of these, 13 were collected, and measurements of axial length, width and height were made on 124 specimens which were not collected. Histograms of these data are presented (Figure 4). These specimens are herein described as a new species of *Pericosmus.* A single specimen from north-east Queensland is also placed in this species. The specimens of *Pericosmus* collected from the North-West Shelf were trawled from depths between 309 to 420 m. They were found associated with three other species of echinoids: *Lovenia gregalis* Alcock, 1893; and species of *Araeosoma* and *Stereocidaris.* This is the first record of *Stereocidaris* from Australian waters, although this latter genus has been described from Miocene rocks of southern Australia (Duncan 1877; Chapman and Cudmore 1934; Philip 1963). The discovery of *Sterocidaris* still living in Australian waters is therefore not unexpected, as it has a wide distribution today. Indeed, Fell (1966) predicted that it was liable to be discovered off the coast of Australia. At a slightly greater depth, of 720 m, *Histocidaris elegans* (Agassiz) was collected. This is the first record of the species from Western Australian waters.

Mortensen (1951: 177) was doubtful whether the specimen from the Great Barrier Reef described by Clark (1932) really was *P. macronesicus.* In the light of the description of many other species of *Pericosmus* since Clark examined the specimen, its affinities are re-assessed. The third species described in this paper is a single specimen collected by the *Nimbus* in 200 m of water off the southern Queensland coast. Although these two specimens are each considered to represent two undescribed species, open nomenclature is employed on account of the paucity of material. It is to be hoped that future collecting off eastern Australia might yield sufficient material to allow these two species to be formally named.

Measurements of specimens were carried out using a vernier calliper to an accuracy of 0.1 mm. Relative size features of the test are expressed as percentages of maximum test length (%TL). Specimens examined in this study are housed in the collections of the Western Australian Museum (WAM), Australian Museum (AM), British Museum (Natural History) (BM) and the National Museum of New Zealand (NMNZ).

Systematics

Order Spatangoida Claus, 1876
Family Pericosmidae Lambert, 1905

Genus *Pericosmus* L. Agassiz, 1847

Type Species

Micraster latus L. Agassiz, 1840: 2; by subsequent designation of de Loriol 1875: 115.

Pericosmus porphyrocardius sp. nov.

Figures 1-3

Holotype

WAM 729.83 (94.4 mm TL), a dried test trawled from foraminiferal rich mud at a depth of 410-420 m, located about 140 n. mi. NNW of Port Hedland, Western Australia (Figure 5), between 18°01'S, 118°17'E and 18°04'S, 118°12'E, at Station SO 2/82/17A of the CSIRO vessel *Soela*, on 3 April 1982; collected by L. Marsh. Water temperature at this site was not recorded, but at adjacent sites at same depth the temperature was 9.6°C.

Paratypes

WAM 730.83 (6 specimens); WAM 731.83 (1 specimen); WAM 732.83 (1 specimen); AM J17014 (1 specimen); and BM 1983.3.4.1; (1 specimen) from the same locality as the holotype; WAM 733.83 (1 specimen), trawled from mud at a depth of 316-309 m (bottom temperature 10.0°C), located about 120 n. mi. NNW of Port Hedland, between 18°22'S, 117°56'E and 18°23'S, 118°54'E at Station SO 2/82/38 of the CSIRO vessel *Soela*, on 11 April 1982; collected by L. Marsh; WAM 734.83 (4 specimens), trawled from mud at a depth of 376 m, located about 150 n. mi. NNW of Port Hedland at 17°58'S, 118°25'E at Station SO 4A/82/8D of the CSIRO vessel *Soela*, on 1 August 1982; collected by J. Fromont.

Other Material

WAM 1127-83 (4 specimens) trawled from 374-377 m, 17°59'S, 118°26'E at Station 40 of F.V. *Endeavour*, 24 August 1983; WAM 1128-83 (6 specimens preserved in alcohol) from the same locality as WAM 1127-83; WAM 1129-83 (1 specimen) trawled from 327-328 m, 18°04'S, 118°22'E at Station 38 of F.V. *Endeavour*, 24 August 1983; WAM 1130-83 (2 specimens) trawled from 351-353 m, 18°01'S, 118°25'E at Station 39 of F.V. *Endeavour*, 24 August 1983. AM J14462; trawled from a depth of 400-420 m, ENE of Raine Island, Queensland at 11°35'S, 144°04'E.

Diagnosis

Test broader than long; low. Anterior notch deep and wide. Peristome quite deeply sunken. Periproct large.

Description

Test cordate; purple; large, maximum length of type series varying between 86.1 mm and 105.9 mm; wider than long, width varying (Figure 4) between 108-121% of axial length (n = 124); maximum width anterior of position of apical system, about one-third TL from anterior ambitus; relatively low, but variable (Figure 4) (47-63% axial length [n = 121]), apex situated anterior of apical system. Anterior notch deep and wide (Figure 1A). Posterior of test transversely truncated or slightly acuminate. Apical system situated anterior of centre, 36-43% TL from anterior ambitus; slightly sunken. Ambulacrum III not sunken adapically; abapically deepens appreciably; pore pairs minute and aligned nearly exsagittally. Anterior paired petals shallow, narrow and long, 36-42% TL; diverge at about 120°; each row possesses about 40 pore pairs; outer pores of each row elongate, inner pores circular; not conjugate. Posterior paired petals shallow, narrow and shorter than anterior pair; 30-34% TL; diverge at about 75°; each row

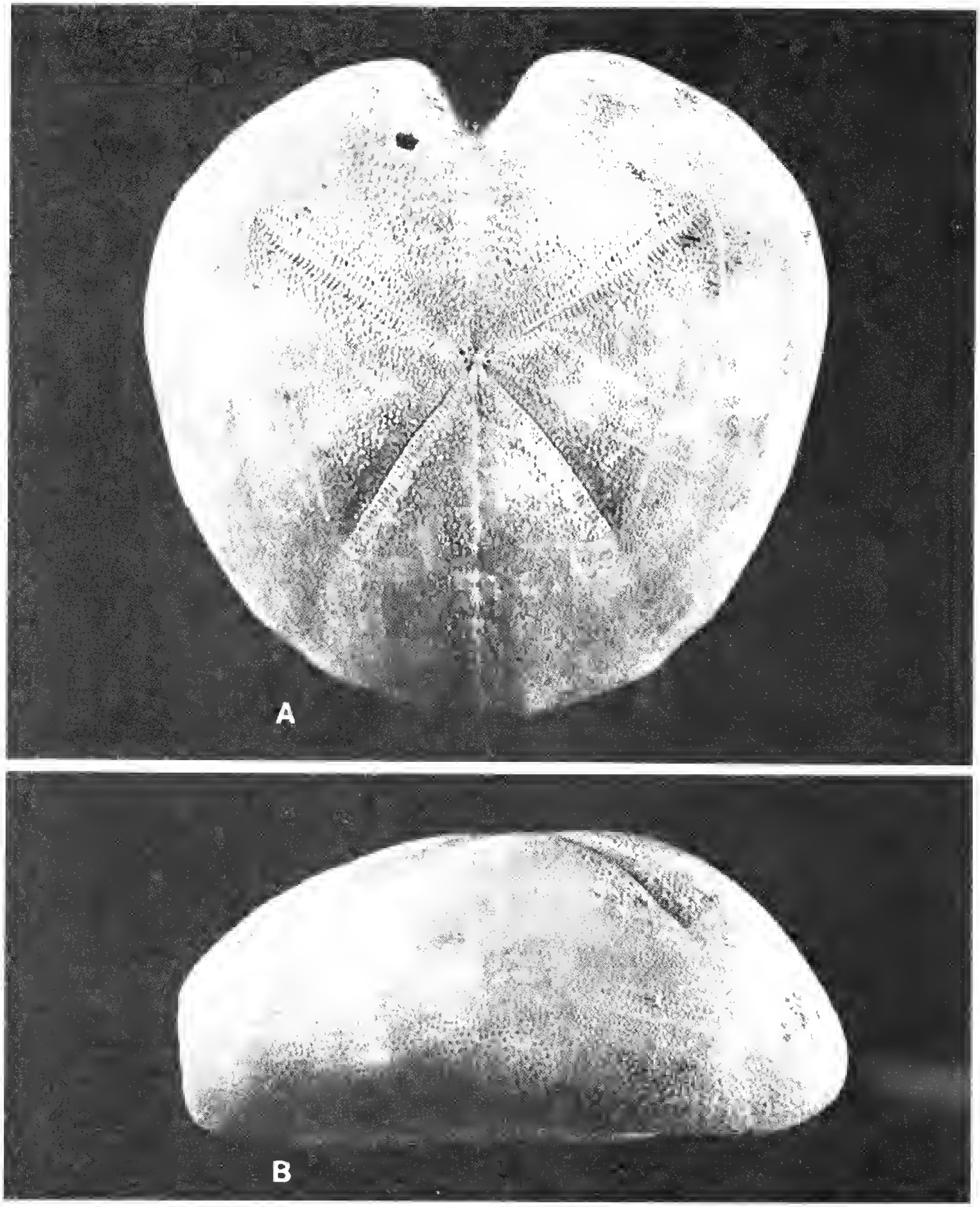

Figure 1 *Pericosmus porphyrocardius* sp. nov., WAM 729.83, holotype from NNW of Port Hedland, between 18°01'S, 118°17'E and 18°04'S, 118°12'E. (A) aboral view; (B) lateral view; both x 1.

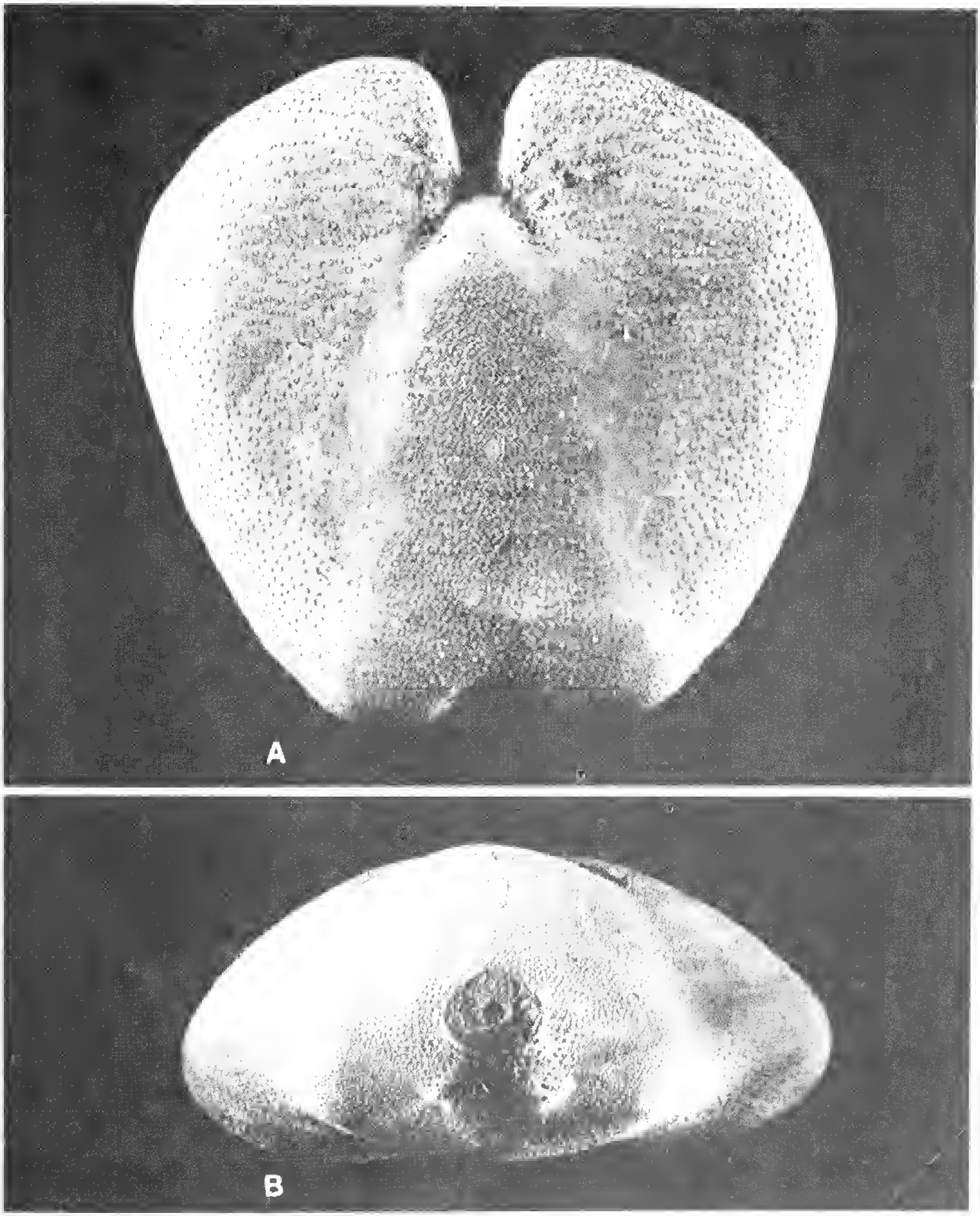

Figure 2 *Pericosmus porphyrocardius* sp. nov., WAM 729.83, holotype from NNW of Port Hedland, between 18°01'S, 118°17'E and 18°04'S, 118°12'E. (A) adoral view; (B) posterior view; both x 1.

possesses about 33 pore pairs. Peripetalous fasciole transverse between posterior petals and runs almost exsagittally between posterior and anterior petals, passing across plate 8 of interambulacra 1a and 4b; may branch in interambulacra 2 and 3, one branch extending almost transversely towards ambulacrum III, before disappearing; main branch turning through a right angle to run exsagittally through two interambulacral plates before crossing ambulacrum III; in some specimens the fasciole may be discontinuous anteriorly. Marginal fasciole runs slightly above ambitus (Figure 1B), crossing plate 4 of interambulacra 1 to 4.

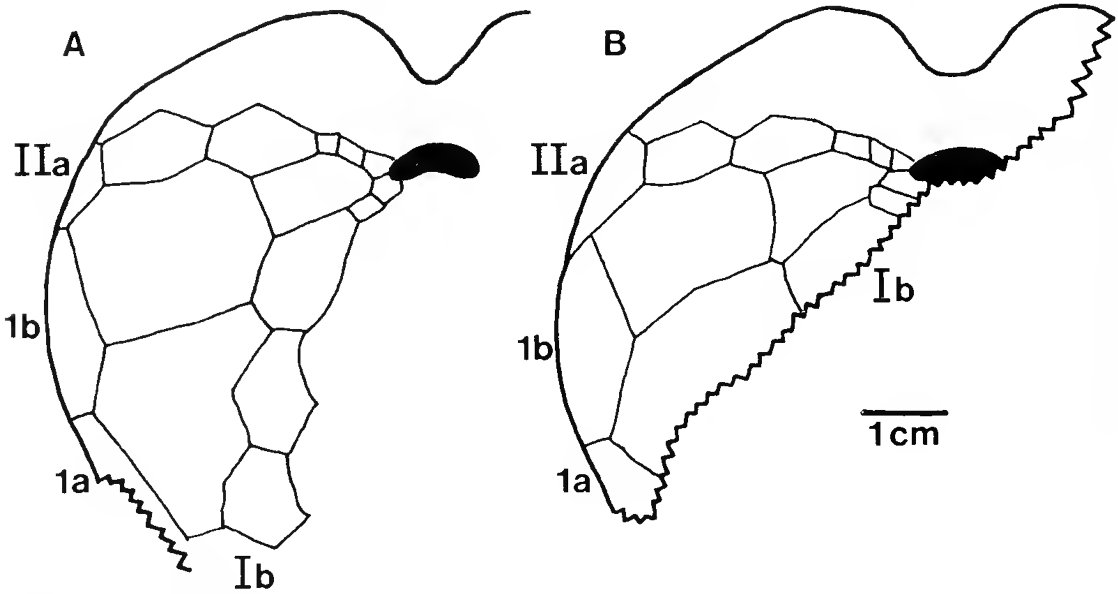

Figure 3 Adoral plating of ambulacrum I and interambulacrum 1 in *Pericosmus porphyrocardius*. In (A), WAM 731.83, the second plate of 1b bisects the plates of 1a to abutt ambulacrum I. In (B), WAM 732.83, the second plate of 1b fails to bisect the plates of 1a.

Adoral surface nearly flat. Peristome lunate, quite deeply sunken; width 11-14% TL. Labrum projects slightly anteriorly (Figure 2A). Plastron narrow, width 26-33% TL. Second plate of interambulacrum 1b greatly enlarged and generally bisects first and second plates of interambulacrum Ia, thus abutting both ambulacra I and II (Figure 3A). Extent of enlargement is variable. In one specimen (WAM 732.83) the second plate of interambulacrum 1b fails to bisect the plates of interambulacrum 1a (Figure 3B). Adoral plates of ambulacrum I are enlarged to varying degrees, particularly plates 3 and 4 of ambulacrum Ib. Periproct sunken (Figure 2B); generally circular, though in some specimens it is longer than wide, while in others it is wider than long; width 11-14% TL. Subanal area also sunken. Spines very short, reaching a maximum length of 5 mm in ambulacrum III aborally. Ophicephalous, tridentate, rostrate, triphyllous and

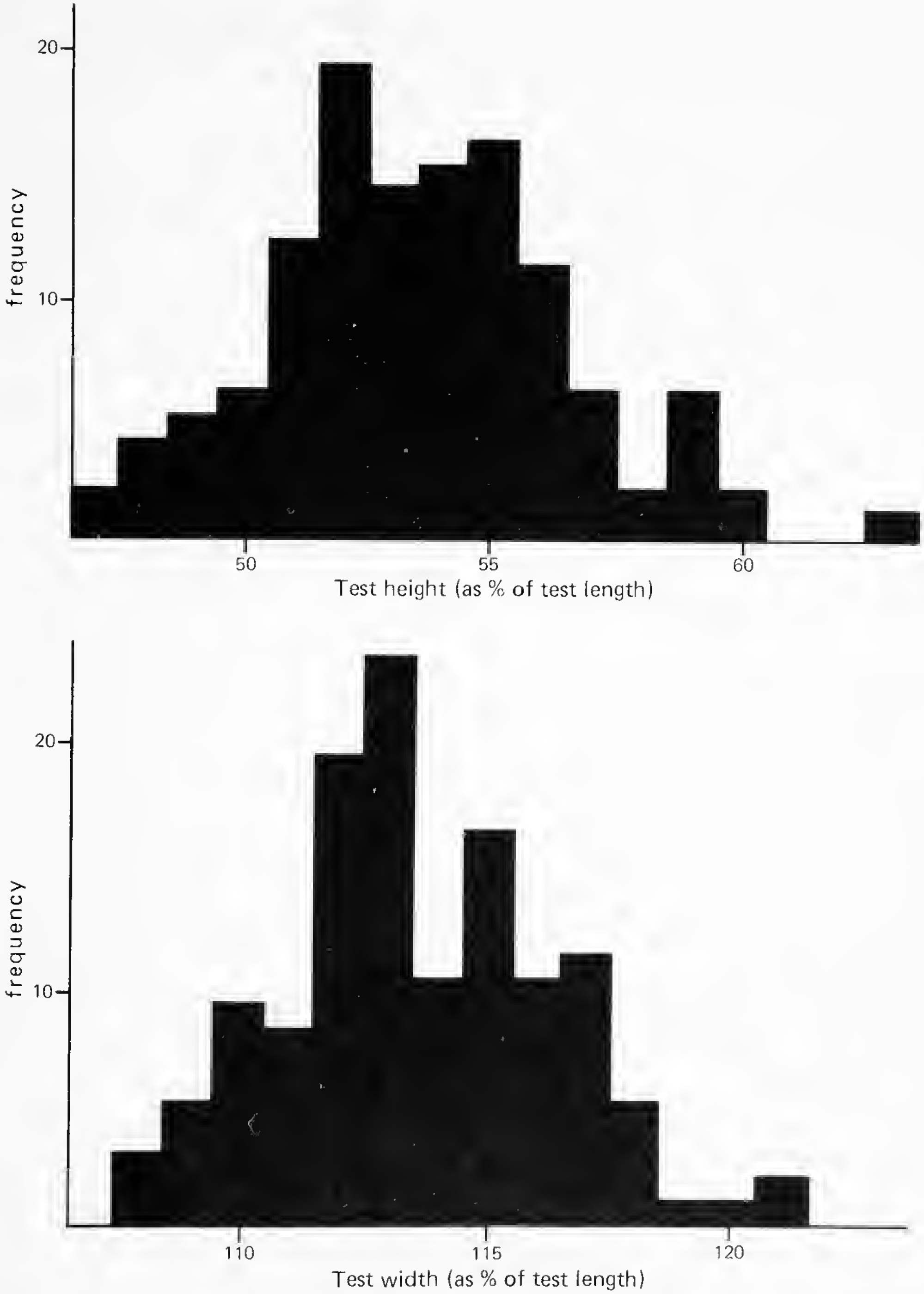

Figure 4 Histograms showing variation of test height and width in *Pericosmus porphyrocardius.*

globiferous pedicellariae present, as in other species of *Pericosmus* (Mortensen 1951: 168). The valves of the ophicephalous pedicellariae are particularly short. These pedicellariae are especially common, over many parts of the test.

Remarks

P. porphyrocardius is a distinctive species totally unlike any other living species of *Pericosmus*. It is morphologically most similar to *P. cordatus*. However it can be distinguished by its possession of a broader, flatter test, which is more posteriorly truncate; longer petals and larger periproct. *P. porphyrocardius* differs from *P. akabanus* and *P. tenuis* in its possession of a broader, flatter test; deeper anterior notch and broader plastron. It can further be distinguished from *P. akabanus* in possessing shorter, narrower petals; less anteriorly projecting labrum;

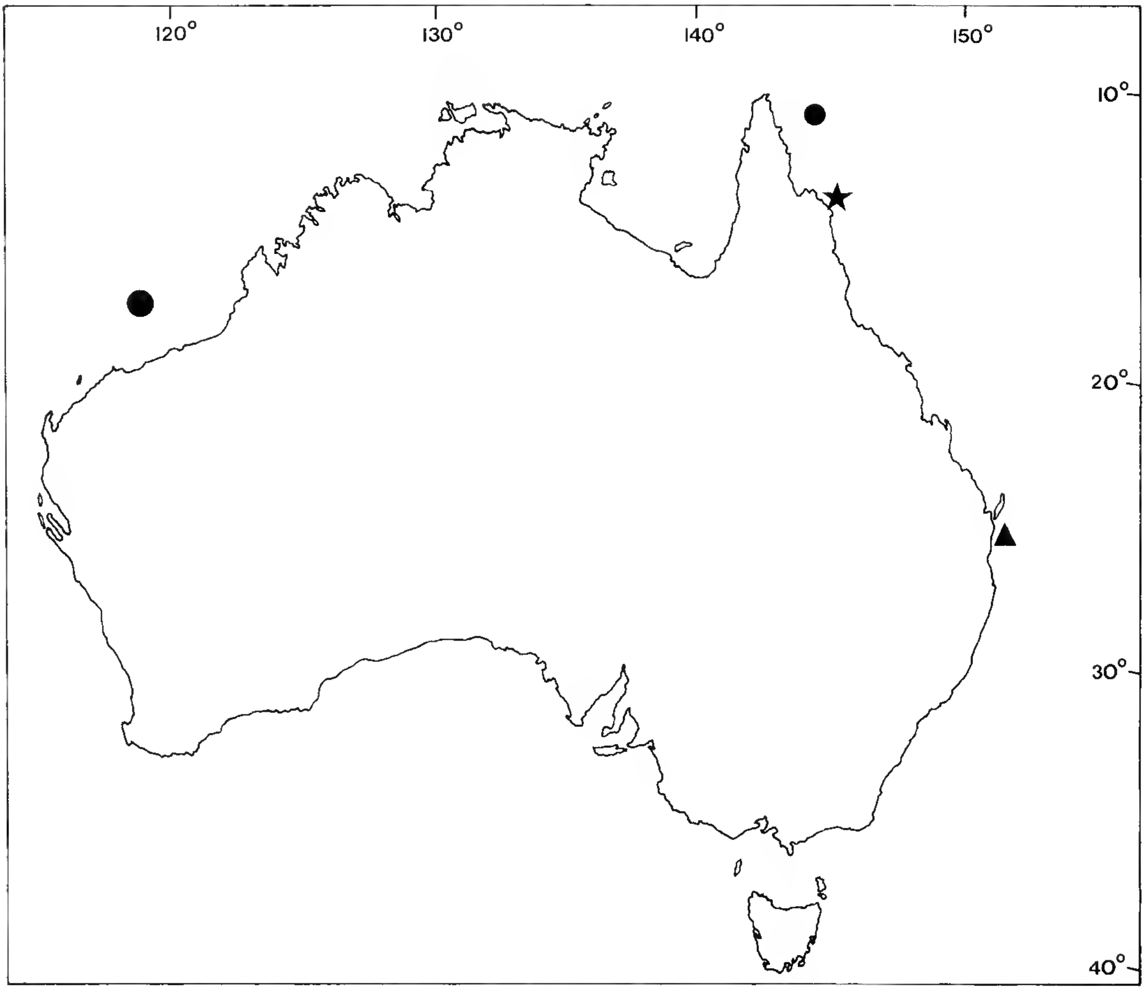

Figure 5 Map showing distribution of the species of *Pericosmus* around Australia; ● = *P. porphyrocardius*; ★ = *Pericosmus* sp. A; ▲ = *Pericosmus* sp. B.

and larger periproct; and from *P. tenuis* in having a more sunken peristome, across which the labrum projects to a greater extent.

McNamara and Philip (in press) in examining fossil species of *Pericosmus* have discussed how it is inappropriate to use the nature of the adoral plating of interambulacrum 1 in the familial placement of *Pericosmus*, a course which had been advocated by Chesher (1968) and Henderson (1975). Examination of the form of the adoral plating in *P. porphyrocardius* reinforces the opinion of McNamara and Philip (in press). The adoral plating of ambulacrum I and interambulacrum 1 shows a high degree of variability in *P. porphyrocardius*. Such intraspecific variability in this character has hitherto not been described in spatangoids. In most specimens the second plate of interambulacrum 1b bisects the plates of interambulacrum 1a to abutt both ambulacra I and II. However, as described above, in some specimens this bisection fails to occur. The size of the adoral plates three and four of ambulacrum Ib is very variable; their expansion greatly affects the size and disposition of the plates in interambulacrum 1. Bisection of the plates in interambulacrum 1a occurs in *P. akabanus* (Mortensen 1951, pl. 15, fig. 6), but not in *P. cordatus* (Mortensen 1951, Pl. 16, figs 6, 7). This variability in the nature of the adoral plating confirms that the use of this character in suprageneric classification in spatangoid echinoids is inadvisable.

Etymology

Porphyra (Gr.): purple; *kardia* (Gr.): heart

Pericosmus sp. A

Figure 6

Pericosmus macronesicus Koehler, 1914; H.L. Clark 1932: 217-218, Plate 1, fig. 4; – H.L. Clark 1946: 363; – Mortensen 1951: 177.

Material

BM1932.1.21.1, from just under 1 km outside Cook's Passage, near Lizard Island, Queensland, 14°31'S, 145°34'E; dredged from 420 m.

Description

Test 60 mm in length; relatively narrow, width 93.8% TL; moderately vaulted, height 62.6% TL; apex at mid test length, posterior of apical system; posterior truncated and inclined adorally. Anterior notch moderately impressed and broad. Apical system situated anterior of centre at 40.3% TL from anterior ambitus; slightly sunken. Ambulacrum III sunken adapically, then shallows slightly abapically before deepening toward ambitus. Anterior paired petals moderately impressed, quite broad; 35.8% TL long; diverge anteriorly at about 115°; each row possesses about 30 pore pairs; pores circular, not conjugate. Posterior paired petals shorter than anterior pair; 28.5% TL; diverge at about 75°; each row possesses about 25 pore pairs. Peripetalous fasciole slightly indented between posterior petals; more strongly indented between anterior and posterior petals; incomplete anteriorly. Marginal fasciole follows the ambitus.

Adoral surface slightly convex. Peristome moderately sunken; broad, 16.2% TL. Labrum projects slightly anteriorly. Plastron very narrow, 20.3% TL. Nature of second plate of interambulacrum 1b unknown. Periproct slightly sunken, slightly broader than long, width 15.3% TL. Subanal area slightly depressed. Pedicellariae as in other species of *Pericosmus.* Ophicephalous pedicellariae particularly densely distributed over periplastronal area.

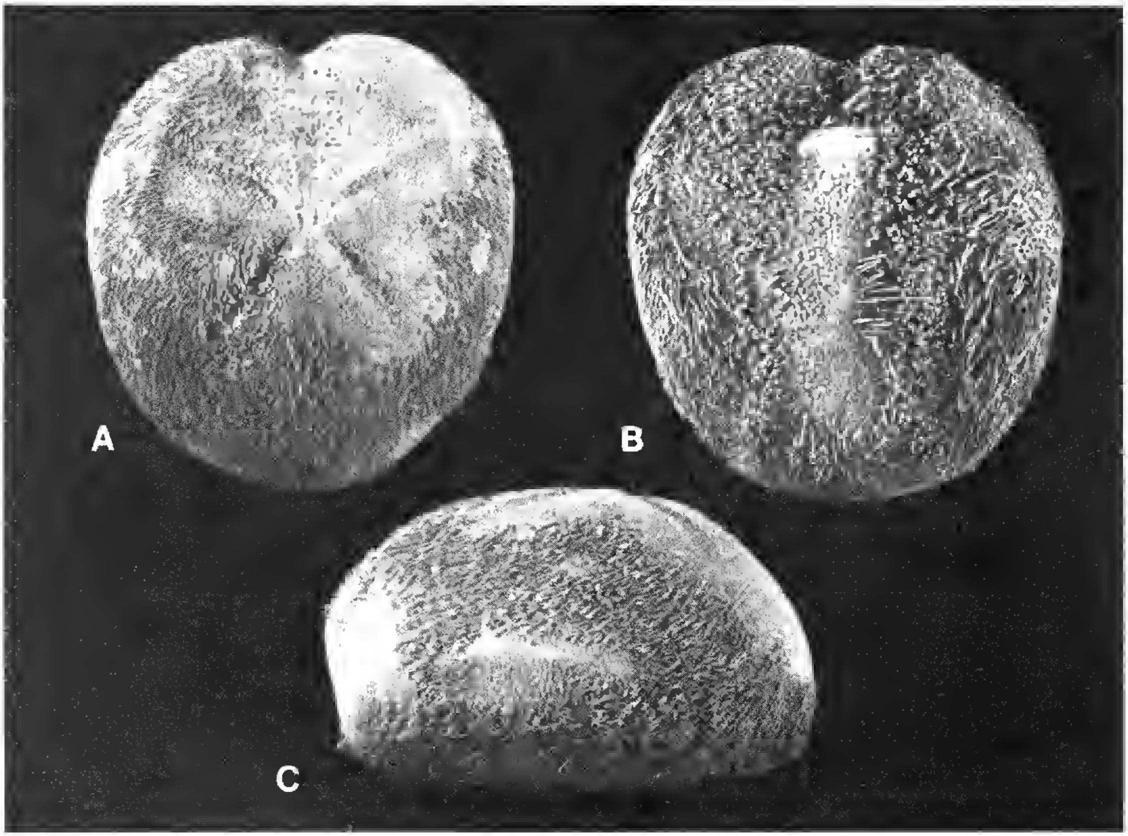

Figure 6 *Pericosmus* sp. A, BM 1932.1.21.1, from just under 1 km outside Cook's Passage, near Lizard Island, Queensland, 16°31'S, 145°34'E. (A) aboral view; (B) adoral view; (C) lateral view; all x 1.

Remarks

Mortensen (1951: 177) expressed doubts over whether this specimen, which H.L. Clark (1932) described, was, as Clark thought, *P. macronesicus.* However, Mortensen gave no reasons for his doubts. Comparison of the specimen with Koehler's (1914, Pl. 7, figs 1-5) type material from the Andaman Islands shows little similarity between the two. *Pericosmus* sp. A has a narrower, slightly higher test; narrower, shallower petals which are appreciably shorter; slightly broader peristome and periproct; much less anteriorly projecting labrum.

Pericosmus sp. A differs from *P. tenuis*, which was dredged off Mauritius, in possessing a deeper anterior notch; a broader, more sunken peristome; and longer anterior petals. It can be distinguished from *P. akabanus*, a Red Sea species, by its much shorter, narrower petals; slightly lower test; and shorter labrum. *Pericosmus* sp. A is probably most similar to the Goto Island species *P. cordatus*, but it has a shallower anterior notch, slightly higher and narrower test. It differs from the Mauritian species *P. bidens* in possessing longer anterior petals, higher test and more anteriorly situated apical system, and from *P. keiensis* also in having longer anterior petals, but possessing a lower test and deeper anterior notch.

Pericosmus sp. A is quite unlike *P. porphyrocardius*, which also occurs in waters off north-eastern Queensland, in its narrower, more tumid test; its shallower anterior notch; its deeper petals; narrower plastron; and shallower periproct and subanal area.

Pericosmus sp. B

Figures 7 and 8

Material

NMNZ ECH.3426, collected from a depth of about 300 m off the southern Queensland coast at 26°30′S, 153°44′E (Station 53 of the *Nimbus*).

Description

Test 39.0 mm in length; narrow and tumid, width 91.9% TL, height 71.8% TL. Maximum width anterior of centre, in line with position of apical system, which is 42.2% TL from the anterior ambitus. Anterior notch broad and shallow. Ambulacrum III deep adapically, but shallows abapically; pore pairs well developed and closely speced, pores being separated by a prominently raised interporal partition. Anterior paired petals broad and moderately deep; diverge at about 120°; 34.1% TL; possess 27 pore pairs in each row; pores in posterior row more widely spaced adapically. Posterior paired petals similarly broad and quite deep; diverge at about 70°; short, 26.0% TL; possess 21 pore pairs. Peripetalous fasciole transverse between posterior petals; slightly indented between posterior and anterior petals, crossing plate 7 of 1a and plates 7 and 8 of 1b; bifurcates in interambulacra 1 and 3, two branches crossing ambulacrum III. Marginal fasciole runs around ambitus, crossing plate 4 of lateral interambulacra. Interambulacra swollen adapically, forming keels.

Adoral surface strongly convex. Peristome small, width 12.5%; barely sunken. Labrum does not project anteriorly. Plastron narrow, width 23.2% TL. Second plate of interambulacrum 1b greatly enlarged and bisects first and second plates of interambulacrum 1a (Figure 8). Periproct small, subcircular, width 11.5% TL. Subanal area hardly sunken.

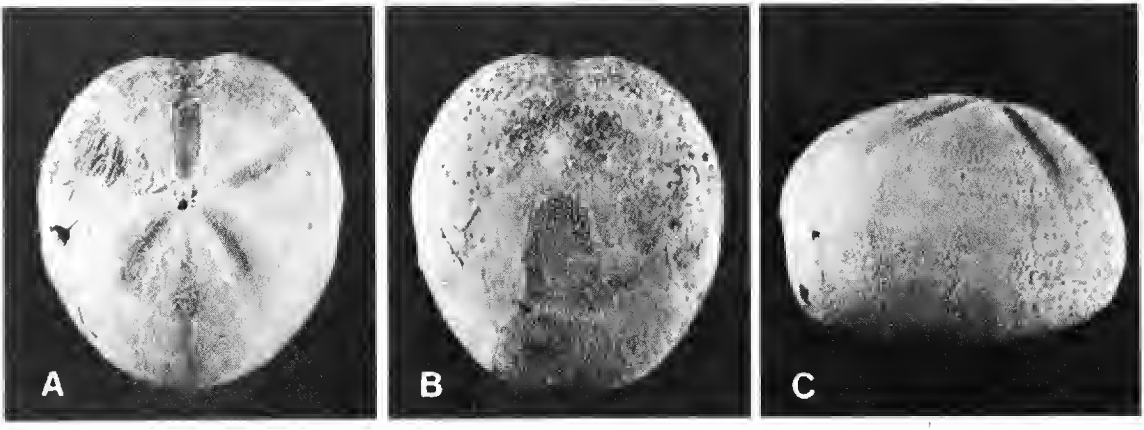

Figure 7 *Pericosmus* sp. B, NMNZ ECH.3426, from off the southern Queensland coast at 26°30'S, 153°44'E. (A) aboral view; (B) adoral view; (C) lateral view; all x 1.

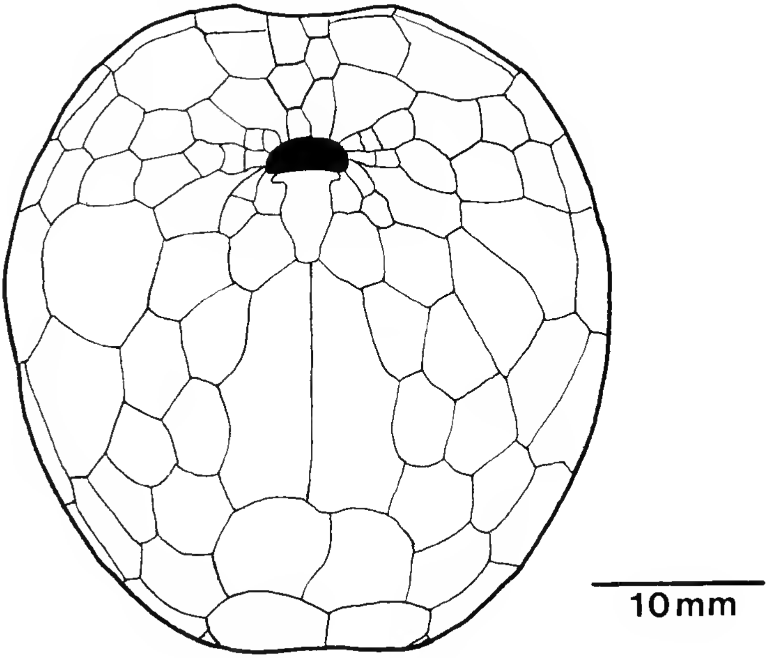

Figure 8 Adoral plating of *Pericosmus* sp. B, NMNZ ECH.3426.

Remarks

Although *Pericosmus* sp. B appears superficially similar to *Pericosmus* sp. A, it possesses a number of significant features which serve to distinguish the two species. The test of *Pericosmus* sp. B is more tumid, the adoral surface in particular being appreciably more convex. Furthermore, *Pericosmus* sp. B possesses a shallower anterior notch; a deeper ambulacrum III adapically; deeper, shorter petals which possess fewer pore pairs; keeled interambulacra adapically; shallower, smaller peristome; shorter labrum; and smaller periproct which is not sunken.

There is little chance of confusing *Pericosmus* sp. B with the other Australian species *P. porphyrocardius,* as they share no features of specific significance in common. *Pericosmus* sp. B differs from *P. tenuis* in possessing sunken petals (they are not sunken at all in *P. tenuis* [Mortensen 1951: 190]); longer, more poriferous petals; tubercles in the interporiferous zone of the petals; and ambulacrum III sunken adapically. The two species possess similar adoral surfaces, although the peristome of *Pericosmus* sp. B is slightly smaller and the surface is a little more strongly convex. *Pericosmus* sp. B can be differentiated from *P. akabanus* on the basis of its much shorter petals; its shallower anterior notch; smaller peristome and periproct; and shorter labrum. It differs from *P. cordatus* in possessing broader petals; shallower anterior notch; more tumid test; and smaller, shallower peristome and periproct.

Pericosmus sp. B compares with *P. keiensis* in possessing a deepened ambulacrum III adapically, and keeled interambulacra adapically. Furthermore, both have a tumid test. However, *Pericosmus* sp. B is distinguished by its more anteriorly situated apical system; its more poriferous, longer anterior petals, which are less divergent; smaller peristome, and posterior of the test which is not vertical, as in *P. keiensis,* but slopes a little adorally.

In addition to having a smaller peristome and more tumid test than either *P. bidens* or *P. macronesicus, Pericosmus* sp. B can be distinguished from *P. bidens* by its shallower anterior notch and broader petals, and from *P. macronesicus* by its shorter petals and shorter labrum.

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Two New Acarid Hypopi (Acari, Astigmata) from the Faeces of the Numbat *Myrmecobius fasciatus* Waterhouse (Marsupialia, Myrmecobiidae)

A. Fain* and J.A. Friend†

Abstract

Cosmoglyphus angustus sp. nov., *C. angustus distinctus* subsp. nov. and *Australhypopus flagellifer* gen. et sp. nov., are described as hypopi (heteromorphic deutonymphs) from the faeces of the Numbat or Banded Anteater in Western Australia.

Introduction

We describe herein new acarid mites represented only by their hypopial stages (heteromorphic deutonymphs), found in the faeces of a female Numbat, *Myrmecobius fasciatus,* captured at Dryandra Forest in the south-west of Western Australia. Remains of termites and one ant were also present in the scat; the hypopi were probably associated with termites, which form the principal part of the Numbat's diet (Calaby 1960).

Systematics

Genus *Cosmoglyphus* Oudemans, 1932

Type Species
Tyroglyphus krameri Berlese, 1881.

Diagnosis (hypopus)

Characteristically shaped. Dorsal surface strongly convex, but margins wide and very thin, forming flat membranes around body and covering basal articles of legs I and II and palposoma. Tibiae and genua I and II bearing very thick posterior spines. Suctorial plate very small, far from posterior margin of body. Posterior legs (III and IV) generally completely ventral.

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Cosmoglyphus angustus sp. nov.

Figures 1, 3-4, 6-8

Holotype

Western Australian Museum (WAM) reg. no. 82/1151; hypopus; taken from faeces of female *Myrmecobius fasciatus* Waterhouse (Marsupialia, Myrmecobiidae) which was released alive; locality: Dryandra Forest, Western Australia, 32°44'S, 116°53'E; 8.vii.1981; coll. J.A. Friend.

Paratypes

(a) Institut royal des Sciences naturelles de Belgique, Brussels (IRSNB); hypopus; collection data as for holotype. (b) Collection of A. Fain; hypopus; collection data as for holotype.

Diagnosis (hypopus)

Body narrow, its anterior margin rounded, setae *sc i* and *sc e* barbed.

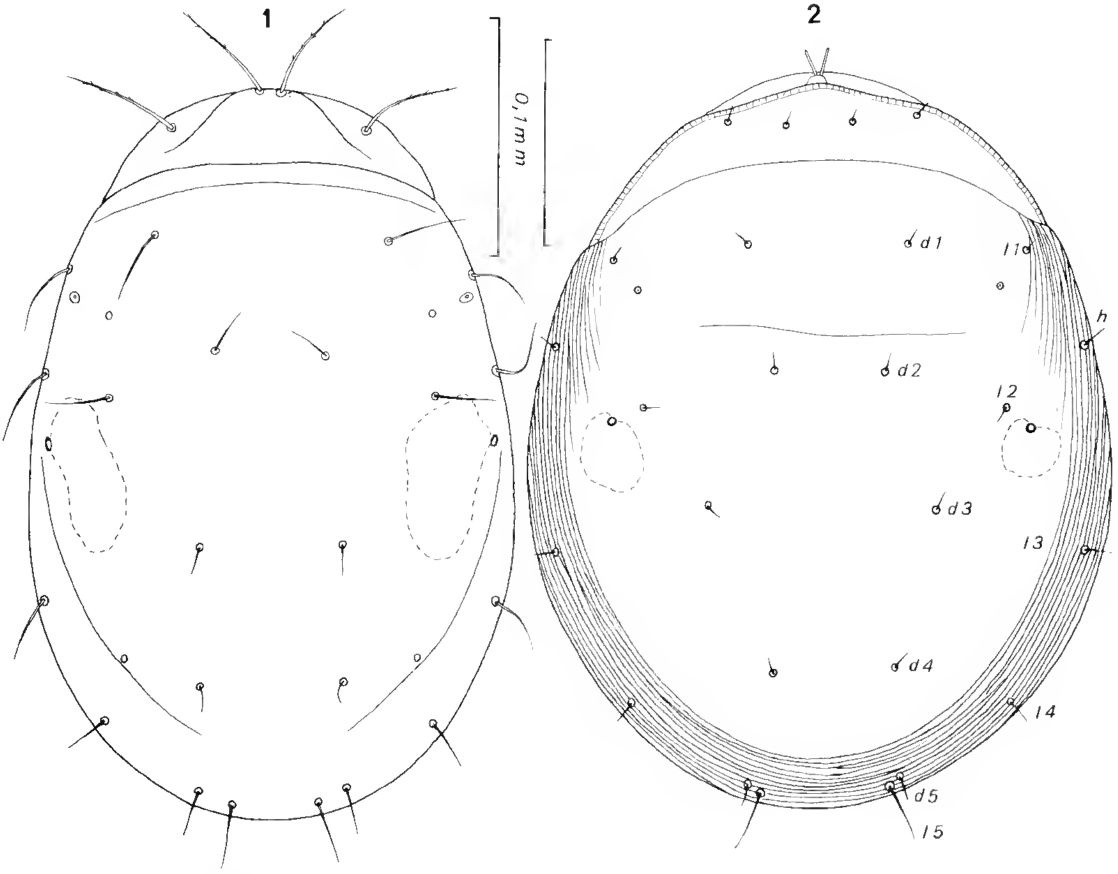
Description (hypopus)

Holotype 306 μm long and 220 μ m wide; paratypes 310 μm x 222 μm and 315 μm x 219 μm. Ratio length/width 1.38 to 1.43. Dorsum: Anterior margin of body wide, membranous. Propodonotum short, setae *sc e* and *sc i* 45 μm long and placed in a convex line. Hysteronotum with thin setae 18 μm to 30 μm long. Venter: *v i* setae 18 μm long. Sternum and epimeres II not reaching posterior margin of coxal fields. Epimeres III and IV long but not reaching anterior margins of coxal fields III-IV. Palposoma 33 μm long, 9-10 μm wide, bearing solenidia α 45 μm long and two pairs of short setae. Suctorial plate small (42 μm wide) with posterior suckers oval (9 μm long, 7,5 to 8 μm wide), and anterior suckers circular (7,5 μm in diameter); lateral conoids situated at same level as posterior suckers. Setae *cx I, cx III* and *g p* modified in conoids; *g a* and *g m* short, piliform. Legs I longer than legs II. Tarsi I to IV 39 μm – 32 μm – 32 μm – 39 μm respectively. Tarsi I with three foliate subapical setae, one longer subapical spoon-like seta, two very slightly foliate preapical setae, one simple preapical dorsal seta, one short preapical ventral spine and one rather long simple posterobasal seta. Tarsus II as tarsus I but spoon-like seta shorter. Tarsi III-IV with five foliate preapical setae and three other simple setae. Tibiae I-II with two spines, one strong posteroventral and one smaller anteroventral. Genua I-II with a strong posteroventral spine and a short dorsobasal spine. Solenidion ω *1* of tarsus I 16-17 μm long, not reaching apical third of tarsus.

Remarks

The genus *Cosmoglyphus* contains 18 species, mostly represented only by their heteromorphic deutonymph (hypopus) and so inadequately described that their identification is difficult. Only the nine following species may be determined with certainty from their hypopial stage: *C. krameri* Berlese, 1881, *C. triscissus* (Vitzthum, 1935), *C. bipilis* (Vitzthum, 1935), *C. tetramorii* (Samsinak, 1957), *C. solenopsidis* (Samsinak, 1960), *C. arushensis,* (Mahunka, 1961), *C. limbata*

(Mahunka, 1974), *C. inaequalis* Fain and Caceres, 1973 and *C. chantalae* Fain and Caceres, 1973. *C. angustus* sp. nov. is clearly distinguished from all nine by the rounded aspect of the anterior margin of the body (sinuous or angulate in the other species), the barbed aspect of the setae *sc i* and *sc e* (simple in the others) and the narrower body.



Figures 1-2 (1) *Cosmoglyphus angustus* sp. nov. Hypopus in dorsal view. (2) *Australhypopus flagellifer* sp. nov. Hypopus in dorsal view.

Cosmoglyphus angustus distinctus subsp. nov.

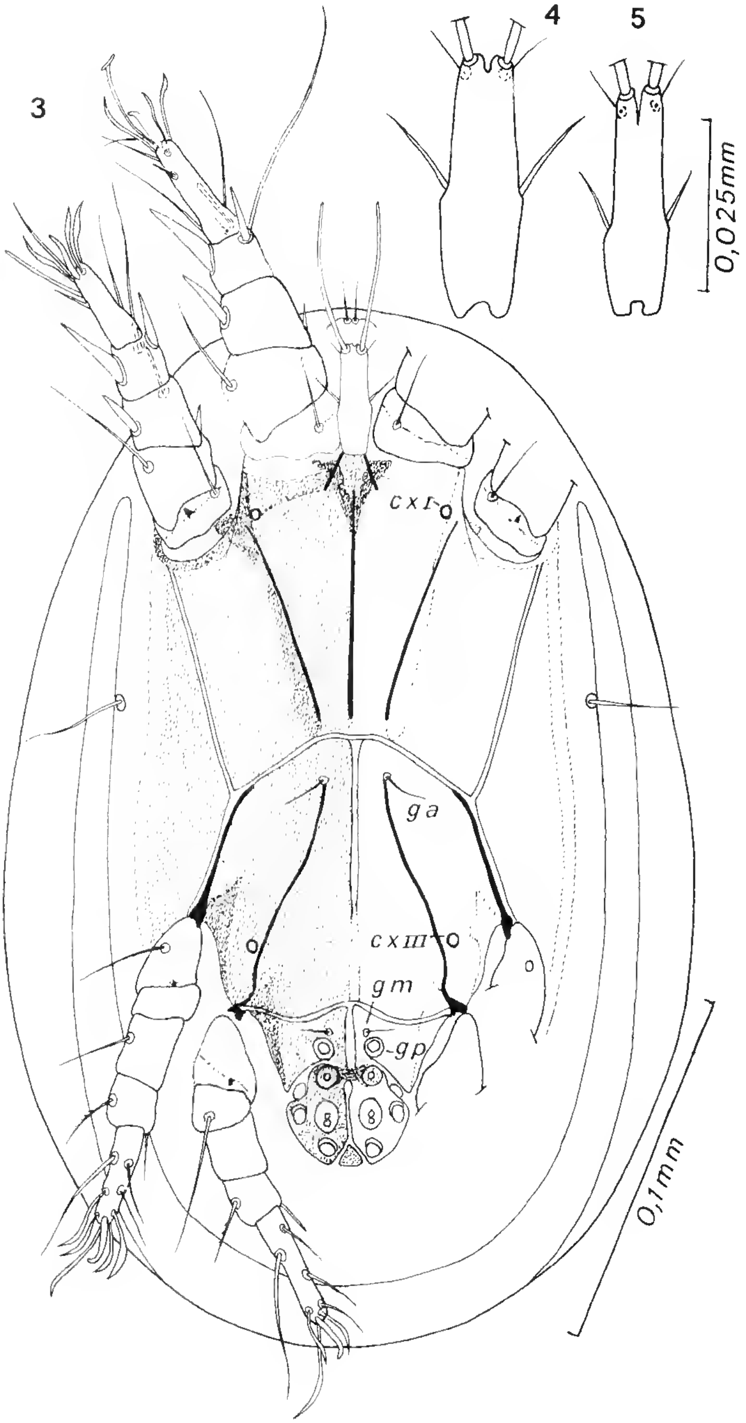
Figure 5

Holotype

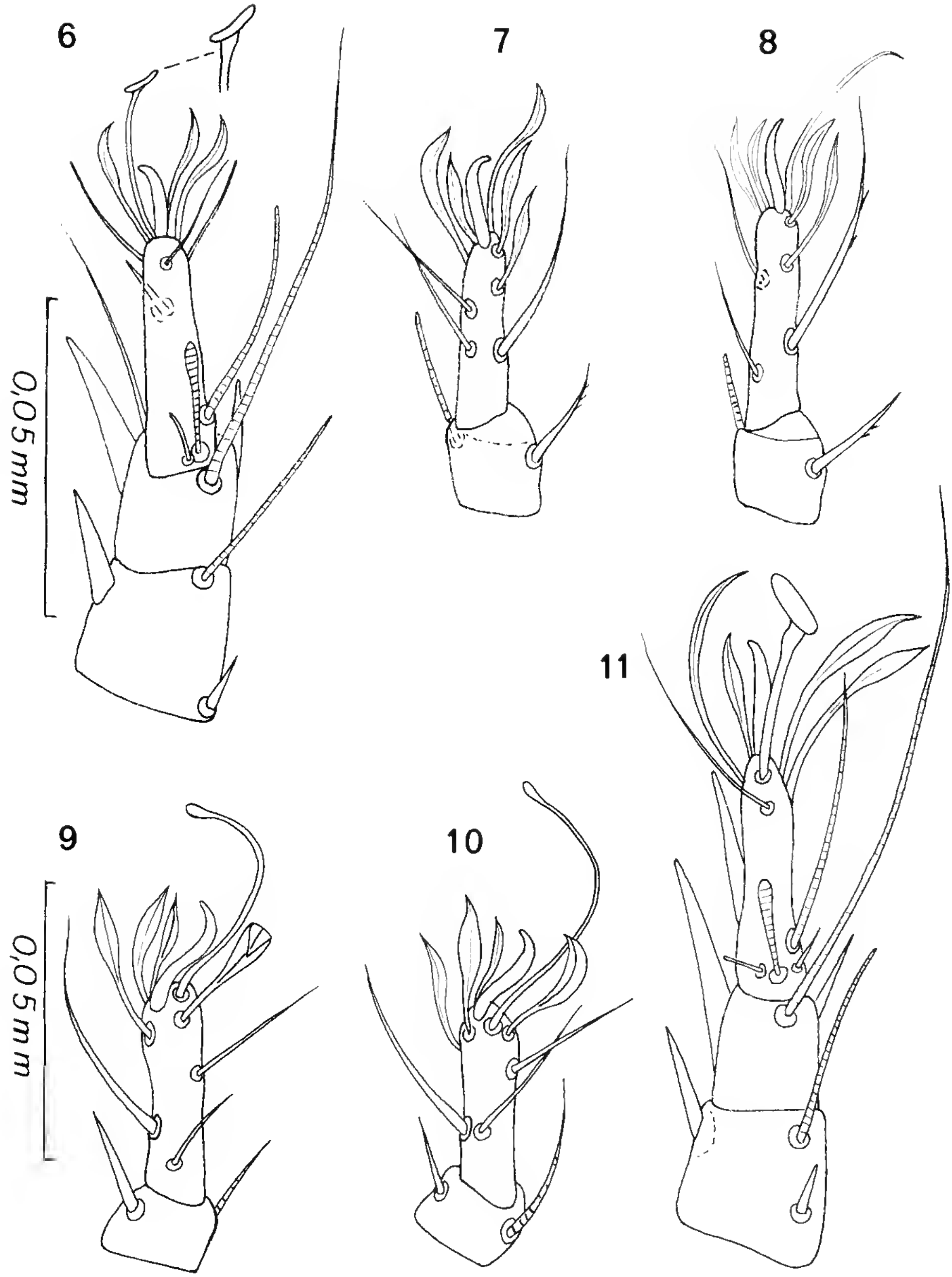
WAM 82/1152; hypopus; collection data as for holotype of *C. a. angustus*, above.

Paratype

Collection of A. Fain; hypopus; collection data as for holotype of *C. a. angustus*, above.



Figures 3-5 (3-4) *Cosmoglyphus angustus* sp. nov. (3) Hypopus in ventral view; (4) Palposoma. (5) *Cosmoglyphus angustus distinctus* subsp. nov. Palposoma. Lower scale line, Figure 3. Upper scale line, Figures 4 and 5.



Figures 6-11 (6-8) *Cosmoglyphus angustus* sp. nov. (6) Leg I dorsally; (7) Leg III; (8) Leg IV. (9-11) *Australhypopus flagellifer* sp. nov. (9) Leg IV; (10) Leg III; (11) Leg I dorsally. Upper scale line, Figures 6-8. Lower scale line, Figures 9-11.

Diagnosis (hypopus)

Differing from typical form as follows: body shorter, less elongate; palposoma shorter and relatively narrower, with posterior setae more posterior; solenidion *ω 1* longer; setae *sc i* and *sc e* shorter.

Description (hypopus)

Holotype 255 μm long and 190 μm wide; paratype 253 μm x 186 μm. Ratio length/width 1.34 to 1.36. Dorsum: Anterior margin and dorsal surface as in typical form. Setae *sc e* and *sc i* shorter (28-33 μm). Hysteronotal setae 15 to 25 μm. Venter: As in typical form except that palposoma is shorter and narrower (27 μm x 6.3 μm) with posterior pair of setae situated more posteriorly (Figure 5). Tarsi I-IV 32 μm – 27 μm – 27 μm – 32 μm respectively. Legs as in typical form but solenidion *ω 1* of tarsus is longer (19 μm), reaching apical third of tarsus.

Genus *Australhypopus* gen. nov.

Type Species

Australhypopus flagellifer sp. nov.

Diagnosis

Body very convex dorsally with margins thin, flat, membranous, covering basal segments of legs I-II and most of palposoma. Anterior margin entire, rounded. A sinuous fold present between sejugal furrow and anterior border of body. Sternum and epimeres II reaching posterior margins of coxal fields I-II. Anterior margin of coxae III with a transverse sclerite which does not reach trochanters III. Palposoma strongly developed, bearing very long solenidia (about three times as long as palposoma), and a very long pair of posterior setae. Legs I slightly longer than legs II. Tarsus I with a relatively very large spoon-like seta, and a rather long posteroventral spine. Tarsi I-IV with four foliate setae. Setae *cx I* and *cx III* piliform. Other characters as in *Cosmoglyphus.*

Remarks

This genus differs from *Garsaultia* Oudemans, 1916 and *Cosmoglyphus* Oudemans, 1932 in the piliform shape of *cx I* and *cx III* setae, and in the abnormal development both of solenidia *α* and of posterior setae of palposoma. It is distinguished from *Cosmoglyphus* by the fusion of a sternum and epimeres II to a transverse sclerite forming the posterior limits of coxae I and II.

Australhypopus flagellifer sp. nov.

Figures 2, 9-12

Holotype

WAM 82/1150; hypopus; collection data as for holotype of *C. a. angustus,* above.

Paratypes

(a) IRSNB; hypopus; collection data as for holotype of *C. a. angustus,* above. (b) Collection of A. Fain; hypopus; collection data as for holotype of *C. a. angustus,* above.

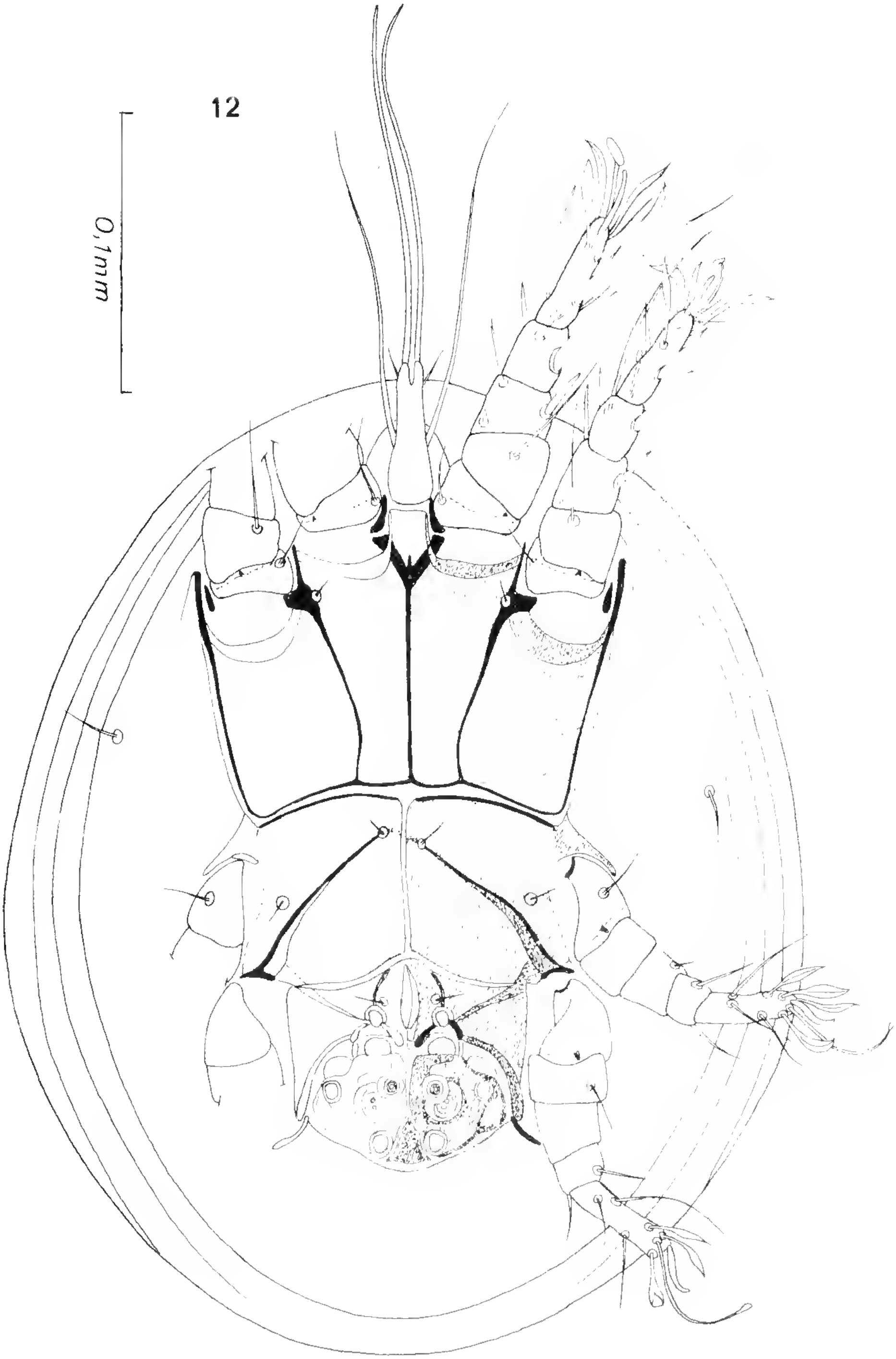


Figure 12 *Australhypopus flagellifer* sp. nov. Hypopus in ventral view.

Description (hypopus)

Holotype 360 µm long, 285 µm wide, paratype 348 µm x 279 µm (second paratype slightly damaged). Dorsum: Anterior margin rounded, there being immediately behind a sinuous fold. Setae *sc e* and *sc i* very short (5-6 µm) situated on a transverse line. Hysteronotal setae thin and short (5-8 µm) but *ℓ 5* longer (25-30 µm). Venter: Sternum and epimeres II long, reaching posterior margin of coxal shields I-II. Transverse sclerite on anterior margin of coxal fields III, not reaching trochanters III. Suctorial plate 70 µm wide. Lateral conoids situated a little in front of posterior suckers. Setae *cx I* and *cx III* are thin, piliform. Palposoma 51 µm long, 16 µm wide (maximum width) bearing two long solenidia α (130 µm) and a pair of very long posterior setae (130 µm). Tarsi I-IV 45 µm — 39 µm — 35 µm — 39 µm long respectively. All tarsi with four foliate setae, in addition tarsi I-II with one spoon-like seta, one simple dorsopreapical seta and one strong posterobasal spine; tarsi III-IV with four simple setae, the apical one with bulbous apex.

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Revision of the *Lerista nichollsi* Complex (Lacertilia: Scincidae)

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Abstract

The *Lerista nichollsi* complex, designated herein, is confined to the arid and semi-arid mid-west and lower north-west of Western Australia. It comprises *L. connivens* Storr, *L. nichollsi petersoni* Storr, *L. nichollsi nichollsi* (Loveridge), *L. uniduo* sp. nov. and *L. onsloviana* sp. nov. and possibly two more taxa.

Introduction

Within the *Lerista bipes* species-group (Storr 1972) there is a cluster of very similar species distinguishable from all others by their possession of prefrontals and a forelimb groove. This cluster of species is herein designated the *Lerista nichollsi* complex. At first (Storr 1972) it was believed to consist only of *L. nichollsi* (mainly in the interior) and *L. connivens* (mainly on the coast). Later (Storr 1976) *L. petersoni* was added to the complex, as a subspecies of *L. connivens.*

In the last seven years, thanks to grants from Mr and Mrs W.H. Butler, the Museum has been able to undertake several herpetofaunal surveys in the vicinity of the mid-west, upper west and lower north-west coasts of Western Australia. During these surveys good numbers of the complex were collected. Identifying specimens of *Lerista connivens* posed no difficulty, but allotting the remainder to either *'nichollsi'* or *'petersoni'* was increasingly unsatisfactory, which has necessitated a revision of the complex.

The principal characters used in discriminating between the species are (1) nature of eyelid (movable in one species, normally immovable in the others); (2) size; (3) habit (one species is as slender as *Lerista bipes,* the rest are noticeably stouter); (4) number of supraciliaries (basically 4, but with fusion of first and/or second to a supraocular they may be reduced to 0 + 2 or 1 + 2); (5) state of second loreal (fused to prefrontal or free); and (6) nature of vertebral stripe (either narrow and enclosing two series of dark spots or wide and enclosing four series of dark spots).

This paper is based solely on specimens in the Western Australian Museum (R suffix omitted from registration numbers), except for the holotype of *Lerista nichollsi,* kindly loaned by the Museum of Comparative Zoology, Harvard.

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Systematics

Key to Species and Subspecies

1 Eyelid movable; supraciliaries normally 4 in continuous series; midbody scale rows commonly (70%) more than 20; vertebral stripe enclosing 2 series of small dark spots . . . . *connivens*

Eyelid immovable (except rarely in *onsloviana*); supraciliaries 1-4, interrupted or in continuous series; midbody scale rows rarely more than 20; vertebral stripe enclosing 2 or 4 series of small dark spots 2

2 Supraciliaries 4, in continuous series; second loreal seldom fused to prefrontal 3

Supraciliaries fewer than 4, owing to fusion of first and/or second to first supraocular; second loreal always or commonly (60%) fused to prefrontal 4

3 Vertebral stripe enclosing 4 series of small dark spots . . . . . *nichollsi petersoni*

Vertebral stripe enclosing 2 series of small dark spots . . . . . . *nichollsi nichollsi*

4 Small (SVL of adults less than 60 mm); body slender; supraciliaries usually 1 + 2 (occasionally 1 + 1, 1 + 3 or 0 + 2); second loreal commonly (40%) free . . . . *uniduo*

Moderately large (SVL of adults commonly more than 60 mm); body relatively stout; supraciliaries 0 + 2; second loreal fused to prefrontal . . . . *onsloviana*

Lerista connivens Storr, 1972

Lerista connivens Storr 1972, J. Proc. R. Soc. West. Aust. 54: 68. Salutation I., W.A.

Diagnosis

A large member of the complex, distinguishable from all others (except occasional specimens of *onsloviana*) by its movable eyelid. It also has more midbody scale rows and fewer nuchals than other species.

Description

Snout-vent length (mm): 33-85 (N 77, mean 63.4). Tail (%SVL): 60-96 (N 36, mean 81.3).

Nasals in short to long contact (N 74) or just touching (2). Supraoculars 3 with first two in contact with frontal (N 75) or 2 with one (2). Supraciliaries 4 (N 75) with first much wider than high and last smallest, or 1 + 2 (1) or 0 + 2 (1). Loreals 2 (N 76) or 1 (1) when second fused to prefrontal. Presuboculars 2 (N 76) or 1 (1). Upper labials 6 (N 76) or 5 (1) when second and third fused to each other.

Nuchals 0 (N 2), 1 (26), 2 (46) or 3 (2). Midbody scale rows 20 (N 24), 21 (4), 22 (47) or 24 (2). Lamellae under longer toe 9-14 (N 76, mean 11.0).

Dorsally brownish-white or greyish-white with a wide vertebral stripe composed of two series of angular, dark brown spots of irregular shape and with longer axis transverse, the space between spots pale to very pale brown; vertebral stripe dilating as it extends forward over head to tip of snout. Wide, dark brown, upper lateral stripe extending narrowly forwards through lore to tip of snout. Upper labials whitish edged with dark brown, margins widest anteriorly. Lower surfaces whitish.

Distribution

Mid-west coast and coastal plains of Western Australia, from Gnaraloo and Mia Mia south to the Murchison and inland to Cooralya, Woodleigh and Nerren Nerren, including several islands in Freycinet Estuary. See Figure 1.

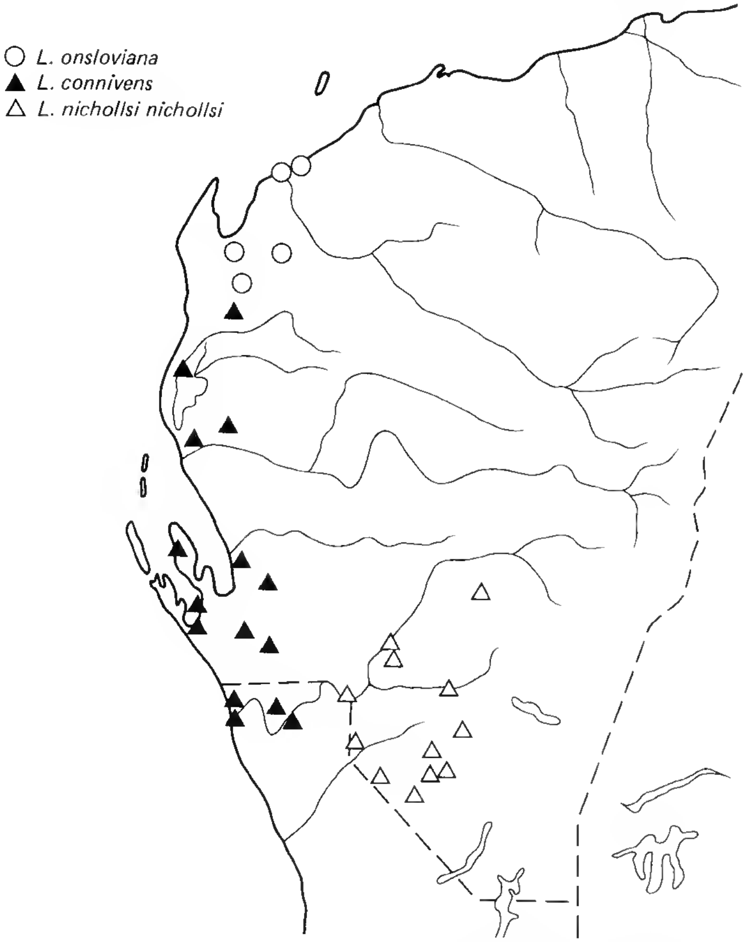

Figure 1 Map of north-western and mid-western Western Australia showing location of specimens of *Lerista onsloviana, L. connivens* and *L. nichollsi nichollsi.*

Material

North-West Division (W.A.)

12 km NW Mia Mia (81833); 18 km E Gnaraloo (76753) and 9 km SE (76713-5, 76870); 27 km SE Cooralya (71394-5); 8 km SSE Boolathana (71336-7); 21 km NNE Carnarvon (71100); 18 km N Yaringa (71128); Denham (81340-1) and 6 km NE (81383) and 2 km N (71090); Woodleigh (57384); Freycinet I. (25811); middle Mary Anne I. (25762-4); south Mary Anne I. (25759-61); Salutation I. (25776-7); Three Bays I. (25750-2); 16 km S Hamelin (76836); 1 km S Tamala (54499-508, 54734, 64404); Coburn (64394); and 17 km NW (63321-2); Wannoo (71068-72) and 6-7 km NNW (64329-32, 64336, 64381, 71132-5) and 6 km S (64312); 17 km SW Nerren Nerren (64317, 64320, 64418) and 31 km SW (64341) and 30 km SE (60630, 60646).

South-West Division (W.A.)

46 km N Galena (59004, 59017) and 30 km NE (73863-5); 10 km N Murchison House (64411); Kalbarri (34317, 40286, 41731, 43857).

Lerista nichollsi petersoni Storr, 1976

Lerista connivens petersoni Storr 1976, Rec. West. Aust. Mus. 4: 253. Yinnietharra, W.A.

Diagnosis

A medium-sized member of the complex with immovable eyelids, 4 supraciliaries and 4 dorsal lines of small dark spots.

Description

Snout-vent length (mm): 31-71 mm (N 23, mean 54.7). Tail (% SVL): 79-109 (N 5, mean 88.0).

Nasals in short to long contact. Supraoculars 3 with first two in contact with frontal, except in one specimen (2 with one). Supraciliaries 4, last much the smallest. Loreals 2 (22) or 1 (1) when second fused to prefrontal. Presuboculars 2. Upper labials 6. Nuchals 2 (N 21) or 3 (2). Midbody scale rows 18 (N 1), 20 (18) or 22 (1). Lamellae under longer toe 9-12 (N 18, mean 11.0).

Dorsally brownish-white with a very wide vertebral stripe composed of four series of small, angular, dark brown spots, the space between them brown to dark brown. Head brown, shields partly edged with dark brown. Wide, dark brown upper lateral stripe extending narrowly forwards through lore to nasal. Upper labials whitish edged with brown, margins darkest and widest anteriorly. Lower surfaces whitish (yellow in life).

Distribution

Upper west and mid-west coasts and adjacent interior of Western Australia, from Barradale south to Kalbarri and nearly to Yuna, and inland to Mt Augustus. See Figure 2.

Figure 2 Map of north-western and mid-western Western Australia showing location of specimens of *Lerista uniduo* and *L. nichollsi petersoni.*

Remarks

A specimen (74947) from Bullara, north-west of the range of *L. nichollsi petersoni,* agrees with that taxon in having immovable eyelids and four supraciliaries but differs in having no stripes. It possibly represents another species or subspecies.

Material

North-West Division (W.A.)

17 km NE Barradale (80251) and 1.5 km W (84187) and 2 km S (80155-7); 10 km N Winning (81828-9); 10 km W Manberry (76842); 6 km SSE Mangaroon (84185-6); Mt Augustus (84087); Yinnietharra (46197, 51378); Denham (81371); 15 km NW Cooloomia (66372) and 14 km W (69543) and 18 km SW (69557) and 23 km SW (66357).

South-West Division (W.A.)

Gee Gie Outcamp (34046); Kalbarri (37640-1); 40 km NE Yuna (57528).

Lerista nichollsi nichollsi (Loveridge, 1933)

Rhodona nichollsi Loveridge 1933, Occ. Pap. Boston Soc. nat. Hist. 8: 97. Dalgaranga, W.A.

Diagnosis

A medium-sized member of the complex with immovable eyelids, 4 supraciliaries and two dorsal lines of small dark spots.

Description

Snout-vent length (mm): 41-68 (N 36, mean 56.4). Tail (% SVL): 69-101 (N 17, mean 90.9).

Nasals in short to long contact. Supraoculars 3, first two in contact with frontal. Supraciliaries 4, last much the smallest (except in one specimen, which has a small additional scale between first and second). Loreals 2 (N 32) or 1 (2) when second fused to prefrontal. Presuboculars 2 (34) or 1 (1). Upper labials normally 6 (in one specimen first and second fused; in another fifth and sixth fused). Nuchals 2 (N 25) or 3 (11). Midbody scale rows 18 (1), 20 (31) or 22 (3). Lamellae under longer toe 9-14 (N 33, mean 11.8).

Dorsally brownish-white with a narrow vertebral stripe composed of two series of short dark brown dashes, the space between them pale to moderately dark brown. Head brown, shields with or without a fine dark brown margin. Wide, dark brown upper lateral stripe extending narrowly forwards through lore to

Figure 3 A *Lerista nichollsi nichollsi* from Yalgoo, photographed by G. Harold.

nasal. Upper lips whitish, posterior margin of labials dark brown. Lower surfaces whitish.

Distribution

Mid-western interior of Western Australia from Mileura south-west to Gullewa. See Figure 1.

Material

North-West Division (W.A.)

Mileura (13477, 15808); Meeberrie (51096); Wooleen (4455); Meka (29272); Dalgaranga (holotype, MCZ 33252); 10 km NE Pindathuna (83803-4, 83807); Yallalong (1262); Wandina (9058); Tallering (54208); Yalgoo (83176-81) and 10 km E (75746); 8 km N Gullewa (83783-99).

Lerista uniduo sp. nov.

Holotype

R71407 in Western Australian Museum, collected by G. Harold and C.D. Winton on 23 October 1980 at 8 km SSE of Boolathana, Western Australia, in 24°43'S, 113°43'E.

Paratypes

For details of 81 specimens see Material.

Diagnosis

A small slender member of the complex with immovable eyelids, usually 3 supraciliaries (the first and second separated by first supraocular) and usually 2 dorsal series of small dark spots. Further distinguishable from *L. nichollsi petersoni* by much higher frequency of second loreal fused to prefrontal.

Description

Snout-vent length (mm): 29-59 (N 82, mean 48.6). Tail (% SVL): 75-102 (N 31, mean 86.7).

Nasals usually in short to moderately long contact, occasionally just touching or very narrowly separated. Supraoculars 3 with first two in contact with frontal. Supraciliaries 1 + 2 (N 72), 1 + 1 (6), 1 + 3 (2) or 0 + 2 (2), last much the smallest and sometimes fused to third supraocular. Loreals 2 (N 34) or 1 (48) when second fused to prefrontal. Presuboculars 2 (N 76), 1 (5) or 3 (1). Upper labials 6. Nuchals 1-3 (N 80, mean 2.3). Midbody scale rows 18 (N 6), 19 (3) or 20 (69). Lamellae under fourth toe 9-14 (N 79, mean 10.9).

Dorsally brownish-white or greyish-white with a narrow to moderately wide, pale to moderately dark brown vertebral stripe enclosing 2 (N 71) or 4 (9) series of small, angular, dark brown spots. Head brown, shields often edged, spotted or smudged with dark brown. Wide dark brown upper lateral stripe extending forwards to temple, thence often narrowly and interruptedly to lore. Anterior and central upper labials edged with dark brown. Lower surfaces whitish (yellow in life).

Distribution

Mid-west coast and hinterland between lat. 22° and 27°S, and inland to Giralia, Binthalya and Mt Narryer. See Figure 2.

Remarks

I tentatively exclude from this taxon three specimens (55971, 55975-6) from 16 km south of Gascoyne Junction; the first is large (SVL 67 mm) and relatively stout and has unusually dark and solid stripes.

Derivation of Name

From Latin *unus* (one) + *duo* (two), in allusion to the supraciliary formula.

Material

North-West Division (W.A.)

Yardie Creek watercourse (61398) and 4 km N (61204); 3 km E Giralia (61399); 17 km E Cardabia (63681); 18 km E Gnaraloo (76749) and 9 km SE (76872-4) and 11 km SSE (81703); Boologooro (31274) and 23 km S (16950); 8 km W Cooralya (76869) and 27 km E (71385); 3 km NW Mardathuna (71352) and 16 km SE (71377-8, 71382); 15 km WNW Binthalya (71603, 71667); 8 km SSE Boolathana (71339-41, 71392-3, 71396-406); 21 km NNE Carnarvon (71101) and 16 km E (41208) and 48 km E (71525-6); 9 km SE Doorawarrah (71598); Callagiddy (37648, 39767, 40667-8); 59 km SSE Carnarvon (55046-7); Wooramel (18198, 19932, 54712) and 32 km NW (81766) and 16 km N (55202) and 12 km N (55187-8); Denham (74946); Woodleigh (48008-9, 49932-6, 57385-7); Hamelin (54879-80, 56482-3) and 7 km W (54865-7) and 15 km E (54764); Overlander (44528*a*); Wannoo (71067, 71099, 71127) and 7 km N (64379-80); 2 km S Mt Narryer (61301); 7 km W Mungawolagudi Claypan (60647) and 6 km NE (60622).

Lerista onsloviana sp. nov.

Holotype

R81073 in Western Australian Museum, collected by G. Harold and C. Winton on 20 August 1981 at Old Onslow, Western Australia, in 21°43′S, 114°57′E.

Paratypes

North-West Division (W.A.)

2 km SW (new) Onslow (80316) and 1 km W (84209-15, 84292-7); Old Onslow (81074-5); 3 km E Giralia (61156-7); 9 km NW Barradale (80193-4, 80240-5); Marrilla (63701).

Diagnosis

A medium-sized member of the complex with usually immovable eyelids, usually 2 supraciliaries (the first and second fused to first supraocular), second loreal fused to prefrontal, and relatively narrow vertebral stripe (enclosing 2 series of dark spots).

Description

Snout-vent length (mm): 39-70 (N 28, mean 55.0). Tail (% SVL): 72-86 (N 12, mean 79.3). Eyelids immovable (N 27) or movable (1).

Nasals usually in short to moderately long contact, occasionally just touching or very narrowly separated. Supraoculars 3 with first two in contact with frontal (4 with 3 on one side of one specimen). Supraciliaries 0 + 2 (N 26), 1 + 2 (1) or 0 + 1 (1). Loreal 1. Presuboculars 2 (26) or 3 (2). Upper labials 6. Nuchals 1 (N 1), 2 (14) or 3 (13). Midbody scale rows 20. Lamellae under longer toe 10-15 (N 28, mean 11.6).

Dorsally brownish-white with a narrow, usually sharply defined, vertebral stripe composed of two series of small, angular dark brown spots or short dashes, the space between them brown or pale brown. Top of head pale brown, shields partly edged with brown. Dark brown upper lateral stripe relatively narrow and extending through lore to nasal, lower edge ragged and tending to break up into a series of spots. Upper labials edged with dark brown, margins darkest and widest anteriorly. Lower surfaces whitish.

Distribution

North-west coastal plains of Western Australia, from Onslow south to Giralia and Barradale. See Figure 1.

Derivation of Name

After the type locality, (old) Onslow.

Discussion

This complex has posed difficulties, not because its members are unusually variable, but because of the small morphological gap between the species. In identifying specimens it is therefore necessary to consider simultaneously most of the six characters listed in the Introduction.

Further collecting is required for ascertaining the taxonomic status of the specimens from Bullara and Gascoyne Junction, mentioned under *L. nichollsi petersoni* and *L. uniduo* respectively.

As a result of this revision, certain faunal lists must be amended. In the Shark Bay list (Storr and Harold 1978) and Zuytdorp list (Storr and Harold 1980), the accounts of '*nichollsi*' are based on both *L. uniduo* and *L. nichollsi petersoni*. In the Exmouth list (Storr and Hanlon 1980) the account of '*nichollsi*' is based on both *L. uniduo* and *L. onsloviana*.

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Re-examination of the Quanbun Local Fauna, A Late Cenozoic Vertebrate Fauna from Western Australia

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Abstract

Re-examination of a collection of fossil bones and teeth from Quanbun Station in the south-western Kimberley, Western Australia, has raised the possibility that the fossils may be Pliocene in age. If so, these bones represent the oldest described mammalian remains from Western Australia. The following taxa are present in the fauna: *Phascolonus* sp. cf. *P. gigas,* Diprotodontoidea indet., *Protemnodon* sp. cf. *P. roechus, Macropus pan,* cf. *Osphranter* and Crocodylidae indet.

Introduction

The State of Western Australia, which comprises approximately one-third of the land mass of Australia, has thus far not yielded a single marsupial fauna of definite Tertiary age. The oldest published mammalian fossils from Western Australia are a P/3 similar to that of the species of *Potorous,* and some bone fragments from a bore at Jandakot near Perth, which are early Pleistocene in age (Balme 1980). Indeed, fossil marsupial faunas of any age except Holocene are extremely rare in the northern three-quarters of the State. The only substantial find reported thus far is the Quanbun local fauna. Glauert (1921) reported the finding of fossil bones during the excavation of a tank on Quanbun Station. Merrilees (1968) notes that the fossil locality is about 15 km north of Quanbun Homestead, and was formerly called Alligator Dam but is now known as Jubilee Dam. The stratigraphy of the site according to Glauert (1921) is as follows: 5 feet of dark, slate-coloured clay which is overlain by a conglomerate of varying thickness (no measurements given). Below this clay is a lighter and softer bone-bearing clay (no thickness given). Glauert identified *'Macropus' (Protemnodon) anak, Phascolonus gigas* and *Crocodylus* sp. in the fauna. Merrilees (1968) gives the faunal list as *Phascolonus gigas,* a large macropodine resembling *Protemnodon anak,* a further large macropodine and a crocodilian. The present author decided that the material warranted further examination upon recognizing *Macropus pan,* previously known only from early-mid Pliocene localities in Queensland, in the fauna.

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Dental terminology and homology follows Archer (1976*a;* 1978). All numbers refer to specimens in the collection of the Department of Palaeontology, Western Australian Museum. As is suggested in Flannery (1980) and Flannery and Archer (1982) the names *Macropus, Osphranter* and *Prionotemnus* are given generic status, although the species composition and status of *Prionotemnus* is at present under revision by the author.

Systematics

Class Reptilia
Order Crocodylia
Family Crocodylidae

Crocodylidae indet.

Material

A very large specimen of a crocodile is represented by two teeth, WAM 66.8.24 and WAM 66.8.23 (see Figure 1), and possibly some postcranial fragments.

Remarks

These teeth are indistinguishable in morphology from the anterior teeth of the largest specimens of *Crocodylus porosus* in the Australian Museum collections, but are slightly larger.

Molnar (1982) has recently reviewed fossil crocodile remains from Queensland. On the basis of his study, it is apparent that the Quanbun teeth cannot be distinguished from those of either *Pallimnarchus pollens* or *Crocodylus porosus.* However, they are unlikely to belong to any other named Australian taxon. *Crocodylus porosus* remains are known from the Pliocene to Recent, while those of *P. pollens* are restricted to Pliocene and Pleistocene sediments (Molnar 1982).

Class Mammalia
Infraclass Marsupialia
Family Vombatidae

Phascolonus sp. cf. *P. gigas* (Owen, 1858)

Material

A large wombat is represented at Quanbun by two incisor fragments, WAM 65.2.34, an I1/ fragment, and WAM 65.2.35, an I/1 fragment.

Description

The I1/ fragment indicates that this tooth was broad and flattened, such as is seen in *Phascolonus gigas* (Figure 1). The I/1 is slightly laterally compressed and indistinguishable in size and morphology from the same tooth in *P. gigas.*

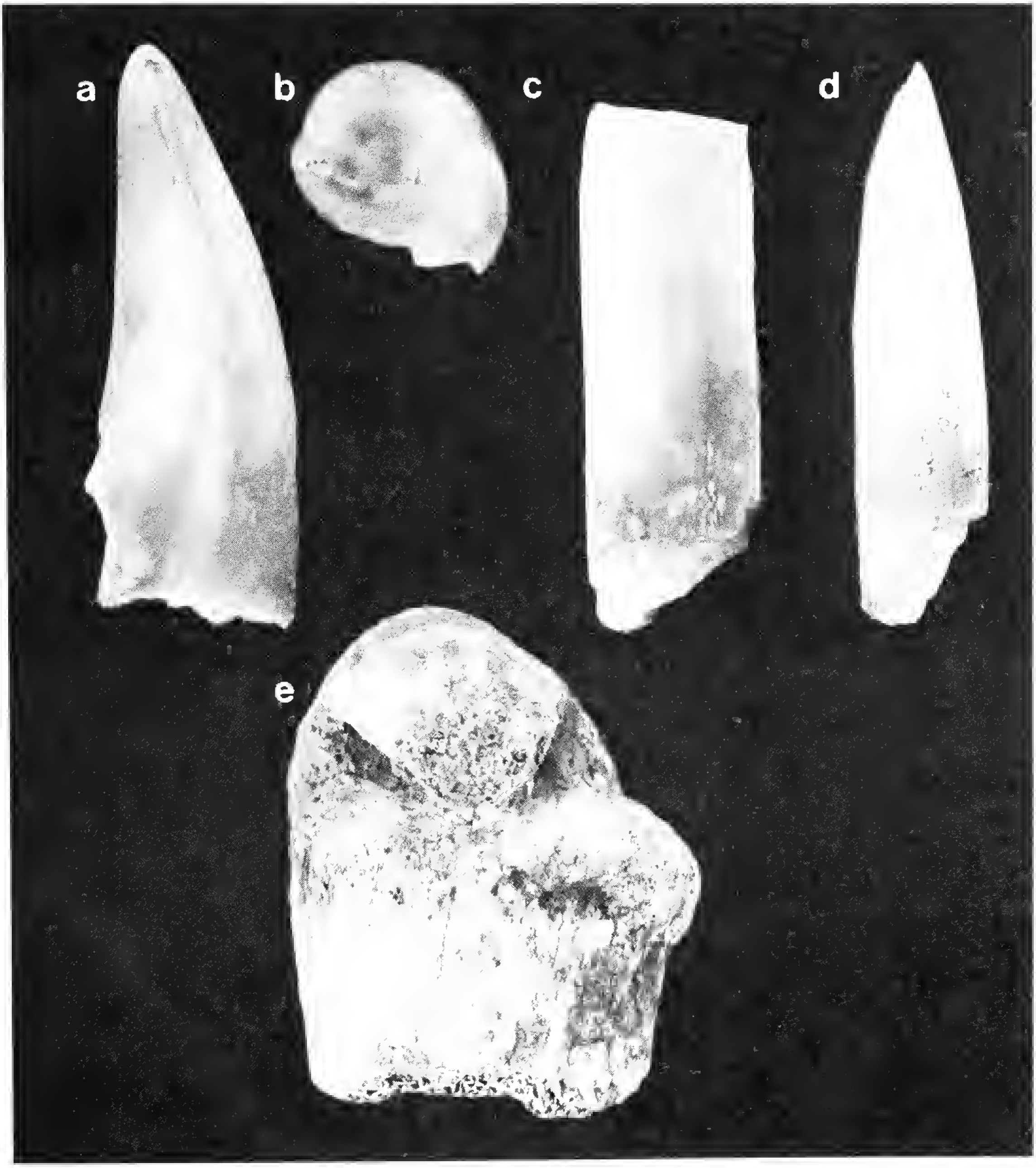

Figure 1 Crocodylidae indet. WAM 66.8.24, in (a) anterior or posterior view and (b) occlusal view. Partial left I1/ of *Phascolonus* sp. cf. *P. gigas* WAM 65.2.34, in (c) buccal and (d) posterior view; (e) Diprotodontoid partial metatarsal WAM 82.7.29 in dorsal view; x 1.25.

Remarks

In being unusually flattened and broad, the Quanbun I1/ fragment is similar to I1/ fragments from the early Pliocene Bluff Downs (pers. obs.) and Bow (Skilbeck 1980) local faunas, and to specimens of *Phascolonus gigas* from many Pleistocene localities. Thus far, only *Phascolonus gigas* is known to possess such upper incisors. However, it is possible that the Pliocene specimens may belong to a separate species. *Phascolonus lemleyi* Archer, 1976*b*, known from the lower dentition from the Bluff Downs local fauna, may belong within the genus *Ramsayia* (Dawson 1981). Its relationship to *Phascolonus*-type material from the Pliocene is at present unknown.

Superfamily Diprotodontoidea

Diprotodontoidea indet.

Material

A diprotodontoid is represented by WAM 82.7.31, the closed, fused roots of a molar, and WAM 82.7.29, the distal end of a metatarsal, probably the fourth (Figure 1).

Remarks

The metatarsal is too massive, and the epiphysis too deeply grooved laterally and medially to belong to a vombatid, and on the basis of size clearly represents a diprotodontoid. It cannot be determined at present whether it represents a diprotodontid or a palorchestid. However, it does not match closely any pedal element of the species of *Diprotodon.*

Family Macropodidae

Subfamily Macropodinae

Macropus pan De Vis, 1895

Macropus pan De Vis, 1895: 124-7, Figs 7, 9-10.
Macropus (Osphranter) pan Bartholomai, 1975: 214, pls 16-18.

Material

Macropus pan is represented in the Quanbun collection by a left dentary fragment containing M/4 (WAM 61.7.9) and four unguals of the fourth toe (WAM 68.10.84, WAM 68.10.83, WAM 68.10.85 and WAM 82.7.48). Other bones of a large species of *Macropus*, possibly *M. pan* are WAM 61.7.12a, a distal fourth metatarsal fragment, WAM 82.7.46, a left fifth metatarsal fragment, and WAM 68.10.79, a right calcaneum.

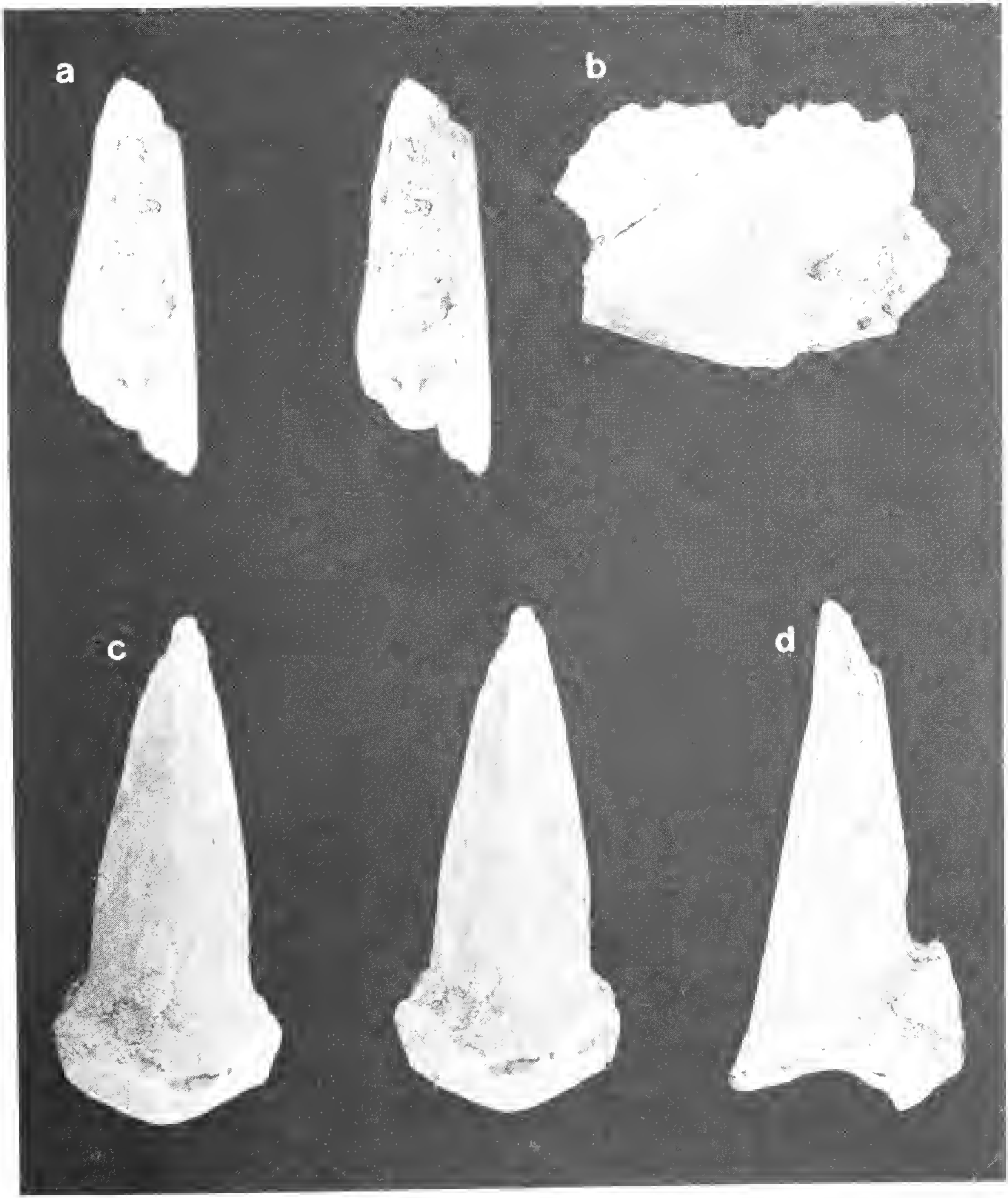

Figure 2 Stereopair of occlusal view (a) and buccal view (b) of left dentary of *Macropus pan*, WAM 61.7.9; and stereopair of dorsal view (c) and lateral view (d) of ungual of fourth toe assigned to *M. pan*, WAM 68.10.84; x 1.

Description

The dentary fragment and M/4 are large, and the dentary is much deeper below the roots of M/2 than below the posterior of M/4 (Figure 2). The dentary is also markedly narrow anterior to the roots of M/2. The M/4 is high-crowned and the lophids have convex rear surfaces. The hypolophid is ornamented by a deep, slightly diagonally placed groove.

Remarks

This specimen is too large to belong to *Osphranter altus, Osphranter woodsi* or *Osphranter pavana* (the M/4 being 18.7 mm in length, the protolophid 11.0 mm in width and the hypolophid 10.2 mm in width). It differs from *M. pearsoni* in lacking the very wide and flaring hypolophid groove, and it differs from *Macropus giganteus, Macropus fuliginosus* and *Macropus mundjabus* in having the hypolophid groove slightly more diagonally placed (see Bartholomai 1975, Flannery and Archer 1982). It also differs from the latter two species in being larger. However, the specimen is consistent in size and morphology with *M. pan.* The status of *Macropus ferragus* is at present uncertain and under revision. However, the Quanbun dentary differs from material referred to *M. ferragus* from western New South Wales (Marshall 1974) in being smaller, and in having a more diagonally placed hypolophid groove.

Further evidence of the existence of *Macropus pan* at Quanbun comes from the unguals of the fourth toe. They are very distinctive in morphology (Figure 2). The bones are large, straight and triangular in cross-section as in most species of *Macropus,* but differ from those of all other species by being slightly upwards-curving, and in possessing slightly concave dorsolateral sides. Although these foot bones have never been found directly associated with teeth of *M. pan,* they are thought to represent this species for the following reasons. Despite a very extensive search of Pleistocene and Tertiary fossil collections in Australian museums, unguals of this morphology have only been found in collections from the Pliocene Chinchilla and Bluff Downs local faunas, Queensland, and from Quanbun. The unguals clearly belong to a very large species of *Macropus,* and differ from those of *M. giganteus* (including large size variants known as *titan*), *M. fuliginosus, M. mundjabus* and *M. ferragus* (material from western New South Wales) which are known and associated with cranial material (see Flannery 1980). At Chinchilla and Quanbun, these unguals are found along with the dental remains of *M. pan,* and this is the largest species of *Macropus* occurring in these faunas. The only other *Macropus* species reported from Chinchilla is *Macropus woodsi,* and this species is clearly too small to be associated with the unguals. Thus it is considered likely that these unguals belong to *M. pan. M. pan* has thus far only been reported from Pliocene sediments.

Protemnodon sp. cf. *P. roechus* Owen, 1874

Material

A large species of *Protemnodon* is represented by WAM 66.7.9, a right M4-5/, WAM 63.11.8, a right I/1, WAM 68.10.77, a left fourth metatarsal, WAM 68.10.78, a left fifth metatarsal, WAM 68.10.82, a proximal phalanx of the fourth toe and WAM 82.7.36, a medial phalanx of the fourth toe. Also, WAM 61.7.11, a right hypolophid, possibly of M/2, and WAM 61.7.10, a left protolophid, possibly of M/3 may come from Quanbun.

Description

The M4-5/ and I/1 are the most diagnostic elements. The right I/1 is moderately worn. The ventral enamel margin is rounded, as in *P. roechus.* In this feature it differs from the I/1 of *P. anak,* which possesses a distinct, sharp ventral enamel flange, not a rounded surface (Figure 3).

Remarks

The I/1 of the Pleistocene *Protemnodon brehus* and the Pliocene *Protemnodon chinchillaensis* and *Protemnodon devisi* are unknown. However, the I/1 of the Pliocene *Protemnodon snewini* is narrower than the Quanbun tooth and also possesses a ventral enamel flange.

The M4-5/ can be clearly distinguished from all species of *Protemnodon* except *P. roechus* by their superior size (Table 1). Bartholomai (1973) reviewed the species of *Protemnodon* from Queensland, and gave revised diagnoses. In morphology, the Quanbun specimen resembles both *Protemnodon brehus* and *P. roechus.* However, the specimen is atypical of *P. roechus* in lacking the tuberculation of the lingual interloph valley often seen in that species (Figure 3). While it is possible that this specimen represents an extremely large form of *P. brehus,* this is considered unlikely, as in all measurements except M5/ length, the Quanbun specimen falls outside the range of variation of the extensive sample from Queensland studied by Bartholomai (1973).

Table 1 Measurements (in mm) for WAM 66.7.9, *Protemnodon,* sp. cf. *P. roechus*; l = length, pw = protolophid width, hw = hypolophid width.

	l	pw	hw
M4/	18.5	15.5	14.3
M5/	18.5	15.3	13.2

Clearly, these specimens do not belong to *P. anak* as previously suggested, nor to any named Pliocene species. The Pleistocene species *P. roechus* and *P. brehus* are difficult to distinguish on the basis of fragmented remains. However, the Quanbun fossils are clearly closer to these species than to other named forms.

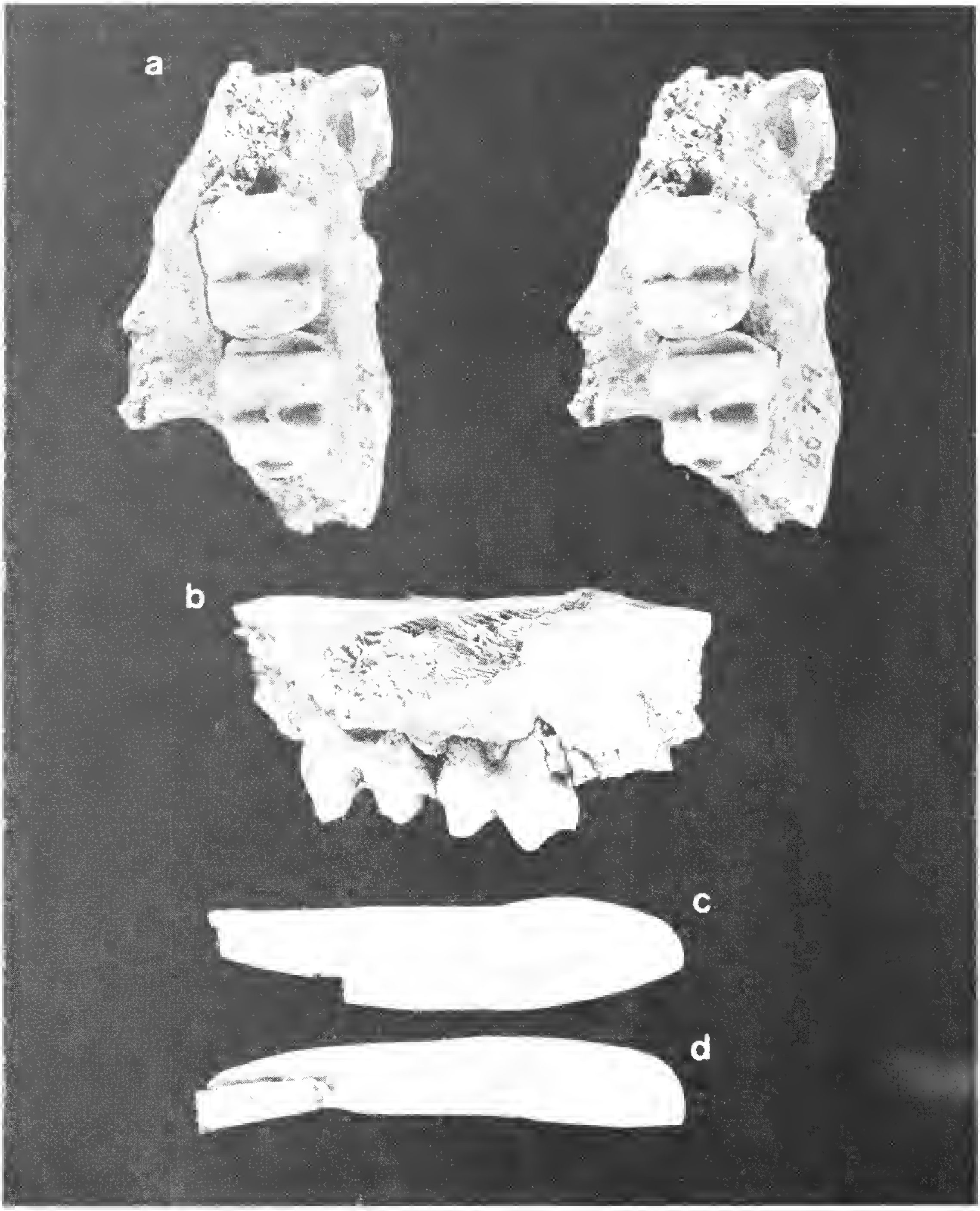

Figure 3 Stereopair of occlusal view (a) and buccal view (b) of M4-5/, WAM 66.7.9, and buccal view (c) and ventral view (d) of I/1 WAM 63.11.8, both of *Protemnodon* sp. cf. *P. roechus*; x 1.

WAM 61.7.10 and WAM 61.7.11 may not form part of the Quanbun local fauna, but may come from Cherrabun according to Merrilees (1968). They are clean of matrix and so unfortunately it cannot be determined if the same greyish-white clay that coats the Quanbun specimens was present on them also. However, if they are from Quanbun and belong to the same *Protemnodon* taxa as the other Quanbun material, WAM 61.7.11 would also be atypical of *P. roechus* in possessing a well-developed posterior cingulum.

cf. *Osphranter*

Material

WAM 61.7.12b, the distal end of a left fourth metatarsal.

Remarks

This specimen may represent a species of *Osphranter*. The distal epiphysis is asymmetrical, the lateral side being noticeably shallower than the medial side. The shaft is also asymmetrical, the lateral side sloping more gently than the medial side. This morphology is characteristic of the species of *Osphranter* (particularly *O. rufus*), and some sthenurines. However, it can be distinguished from species of *Simosthenurus* and *Procoptodon* in that the central keel of the distal epiphysis is more prominent than in those forms (see Tedford 1966). However, the possibility that it belongs to a species of *Sthenurus* cannot be discounted.

Discussion

At present our only extensive knowledge of the late Cenozoic fossil mammals of north-western Australia is derived from the Quanbun local fauna. Because of the nature of the remains, and a lack of sites for comparison in the area, the age and significance of the fauna are difficult to evaluate. The association of *Macropus pan* (elsewhere known only from the Pliocene of Queensland) and a large species of *Protemnodon* similar to *P. roechus* (known from the Pleistocene of eastern Australia) is unique to this site, and could be interpreted in several ways. Either the site is Pleistocene in age and the occurrence of *M. pan* is due to its survival in the Kimberley region after its extinction further east, or it is Pliocene in age and the large *Protemnodon* represents a new species, or an early occurrence of *P. roechus*.

Apart from the occurrence of these taxa together, the rest of the fauna is rather representative of Pliocene and Pleistocene faunas from elsewhere, particularly northern Australia. Unfortunately, little more can be said in terms of age or significance at present. However, the possibility of confirming the presence of Tertiary mammals in Western Australia should act as a strong incentive to re-excavate the site.

Conclusions

The Quanbun local fauna is late Cenozoic in age. It consists of Crocodylidae indet., Diprotodontoidea indet., *Phascolonus* sp. cf. *P. gigas, Protemnodon* sp. cf. *P. roechus, Macropus pan* and cf. *Osphranter.*

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Description of a New Gobiesocid Fish from South-Western Australia, with a Key to the Species of *Aspasmogaster*

J.B. Hutchins*

Abstract

A new species of clingfish, *Aspasmogaster occidentalis*, is described from south-western Australian seas. It is distinguished from other members of *Aspasmogaster* by the absence of anterior skin folds on the ventral surface of its lower lip. *Aspasmogaster liorhynchus* Briggs, originally described from New South Wales is recorded for the first time from Tasmania, Victoria, South Australia and Western Australia. *Aspasmogaster costatus* (Ogilby) from New South Wales, previously united with *A. tasmaniensis* (Günther) is recognized as a distinct species. A key is provided for the species of the genus.

Introduction

The clingfish genus *Aspasmogaster* consists of small fishes which inhabit rocky bottoms in intertidal and shallow subtidal areas of temperate Australian seas and estuaries. The genus was last reviewed by Briggs (1955), who recognized two species, *A. tasmaniensis* (Günther) from southern Australia and *A. liorhynchus* Briggs from New South Wales. Recent collections by the present author have led to the discovery of a third species which is thus far known only from south-western Australia. These collections have also extended the known range of *A. liorhynchus* to Tasmania and west to the Archipelago of the Recherche in Western Australia. Furthermore, the common New South Wales species originally described as *A. costatus* (Ogilby), but synonymized by Briggs with *A. tasmaniensis* is considered to be significantly distinct to warrant specific recognition. The purpose of this paper is to describe the new Western Australian species, to present details regarding the above observations of its congeners, and to provide a key to the genus *Aspasmogaster*.

The methods used follow Hutchins 1983. The material examined is housed at the following institutions: Australian Museum Sydney (AM); British Museum (Natural History), London (BMNH); National Museum of Victoria, Melbourne (NMV); Queen Victoria Museum, Launceston, Tasmania (QVM); South Australian Museum, Adelaide (SAM); and the Western Australian Museum, Perth (WAM).

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Systematics

Key to the Species of *Aspasmogaster*

1a Lower lip smooth-edged, without anterior fold of skin on each side (Figure 1); colour in life either pale yellowish-brown, pinkish-brown or dusky brown, adults with small brownish spots on dorsal surface of head, juveniles dorsally with orange lines and spots across head and body, becoming fainter posteriorly (Western Australia) .... *A. occidentalis* sp. nov.

1b Ventral surface of lower lip with obvious anterior fold of skin on each side (Figure 2); colour not as above 2

2a Snout smooth, no skin fold across its dorsal surface (Figure 2a); colour in life either pale greenish-brown, pale brown or dusky brown, head and body usually covered with many very small darker spots, some of which join together forming short irregular lines (New South Wales, Victoria, Tasmania, South Australia and Western Australia) .... *A. liorhynchus* Briggs, 1955

2b Prominent skin fold across dorsal surface of snout (Figures 2b and 2c); colour not as above 3

3a Pectoral fin rays usually 23 (21-25); dorsal fin rays 8-9; anal fin rays 6-8; vertebrae 30; maximum size 51 mm SL; colour in life pale pinkish-brown with darker irregular cross bars, those anteriorly often merging together to form a complex pattern of irregular blotches (after death this pattern usually disappears) (New South Wales) .... *A. costatus* (Ogilby, 1885)

3b Pectoral fin rays usually 25 (24-26); dorsal fin rays 8-10; anal fin rays 7-9; vertebrae 32; maximum size 67 mm SL; colour in life either yellowish, brownish, pinkish or greenish with darker cross bars, mostly regular in shape and numbering 17-25; rarely body bars fade posteriorly to form scattered pale spots (colour pattern generally remains distinct while specimens reasonably fresh) (Victoria, Tasmania, South Australia and Western Australia) .... *A. tasmaniensis* (Günther, 1861)

Aspasmogaster occidentalis sp. nov.

Figures 1, 3, 4 and 5; Table 1

Aspasmogaster tasmaniensis – Hutchins, 1977: 36 and 174 (part)
Aspasmogaster species – Hutchins and Thompson, 1983: 76 and Fig. 66.

Holotype

WAM P.27882-001, 66 mm SL, Bunker Bay, Cape Naturaliste, Western Australia (33°32'S, 115°02'E), collected with rotenone at 0.5 m, J.B. Hutchins, 8 December 1982.

Paratypes

Seventeen specimens from Western Australia, 22-93 mm SL (unless otherwise designated, all specimens at WAM): P.25770-022, 3 specimens, 22-80 mm SL (52 mm specimen cleared and stained), Sandy Hook Island, Archipelago of the Recherche, rotenone at 13 m, J.B. Hutchins and C.W. Bryce, 11 April 1977; P.25774-008, 55 mm SL, Gull Island, Archipelago of the Recherche, rotenone at 10 m, C.W. Bryce, 15 April 1977; P.26000-013, 23 mm SL, Lucky Bay, east of Esperance, rotenone at 10 m, J.B. Hutchins, 12 March 1978; P.26002-007, 25 mm SL (cleared and stained), unnamed island in eastern Lucky Bay, rotenone at 4 m, J.B. Hutchins, 14 March 1978; P.26007-006, 70 mm SL, Rob Island (off Lucky Bay), rotenone at 10 m, J.B. Hutchins, 20 March 1978; P.26009-003, 68 mm SL, Lucky Bay, rotenone at 13 m, J.B. Hutchins and R.H. Kuiter, 22 March 1978; P.26546-005, 62 mm SL, Saddle Island (off Walpole), rotenone at 3 m, J.B. Hutchins, 5 February 1979; P.26620-004, 26 mm SL, Geordie Bay, Rottnest Island, rotenone at 5 m, J.B. Hutchins and N.O. Sinclair, 14 June 1980; P.27880-003, 3 specimens, 67-93 mm SL, collected with holotype; AM I.20219-024, 58 mm SL, Rob Island (off Lucky Bay), rotenone, B.C. Russell, 20 March 1978; AM I.20222-018, 2 specimens, 31-85 mm SL, Mondrain Island, Archipelago of the Recherche, rotenone, B.C. Russell and R.H. Kuiter, 21 March 1978; BMNH 1983.3.1.2, 69 mm SL, collected with holotype; NMV A.2831, 54 mm SL, collected with P.26000-013.

Diagnosis

This species is placed in the genus *Aspasmogaster* as it lacks the posterior patch of papillae on the anterior half of its ventral sucking disc, as well as having three pores in its lacrymal series, a character combination unique amongst Australian temperate gobiesocids. It is distinguished from all other *Aspasmogaster* species by the absence of two prominent anterior skin folds on the ventral surface of the lower lip.

Description

Measurements and counts of the holotype and selected paratypes are presented in Table 1. The following counts and proportions in parentheses represent the ranges for the paratypes when they differ from those of the holotype.

Dorsal fin rays 9 (8-10; three with 8 and four with 10); anal fin rays 8 (7-9; one with 7 and two with 9); pectoral fin rays 27 (24-27, usually 25); pelvic fin rays I, 4; caudal fin rays 10-12 (from cleared and stained material); vertebrae 32; branchiostegals 6.

Body robust, moderately depressed anteriorly and compressed posteriorly, depth 5.5 (6.2-7.2) and width 5.1 (4.8-5.6), both in SL; caudal peduncle very short, length 1.9 (1.9-3.3) in its depth; head wide posteriorly and moderately depressed, tapering to a rather pointed snout, head length 2.6 (2.4-2.7) in SL and head width 1.7 (1.6-1.8) in its length; snout triangular in shape (dorsal view), length about equal to width (usually somewhat narrower in females) and 3.2 (3.1-3.6) in head length; nostrils relatively small, anterior one located above or just in front of anterior margin of eye, posterior nostril a short distance behind anterior margin of eye; both nostrils tubular, anterior one more prominent with a simple to multilobed flap on posterior half of rim; eye moderate, diameter 4.9 (4.4-5.2) in head length; bony interorbital narrow, width 8.6 (7.0-8.6) in head length.

Table 1 Measurements (mm) and counts of the holotype and selected paratypes of *Aspasmogaster occidentalis.*

	Holotype	Paratypes			
	WAM P.27882-001	WAM P.27880-003	WAM P.25770-014	WAM P.25774-008	AM I.20222-018
Standard length	66	93	80	55	31
Head length	25	34	30	22	13
Head width	15	21	17	12	7.1
Body depth	12	13	13	8.8	5.0
Body width	13	17	15	10	6.5
Snout length	7.9	11	8.7	7.0	3.6
Eye diameter	5.1	6.8	6.2	4.6	2.9
Bony interorbital width	2.7	4.5	4.3	2.6	1.8
Snout to origin of dorsal fin	51	71	62	43	23
Caudal peduncle length	3.3	3.0	2.3	2.1	1.7
Caudal peduncle depth	6.3	8.6	7.5	5.3	3.2
Caudal fin length	9.8	13	12	8.3	5.0
Ventral disc length	17	23	19	13	7.3
Ventral disc width	15	19	17	12	6.4
Dorsal base length	13	20	18	12	7.0
Anal base length	11	18	16	10	5.6
Dorsal fin ray count	9	9	10	9	10
Anal fin ray count	8	8	9	8	8
Pectoral fin ray count	27	26	25	26	25

Skin smooth and scaleless, usually covered with a thick mucous layer (a series of transverse skin ridges on body is probably due to shrinkage during preservation); two lateral line systems present; first consists of well developed open pores found only on head (Figure 1); each pore usually has a short tubular opening slightly longer than thickness of mucous and served by a canal in the underlying bones (outlines of canals indicated in Figure 1); a total of 11 open pores on each side of head is made up of three lacrymal pores, two nasal pores, two postocular pores and four preoperculomandibular pores; second system consists of minute papillae arranged in consistent patterns on head and body, those on latter in two longitudinal series (due to the difficulty in detecting these papillae, they are not described further here).

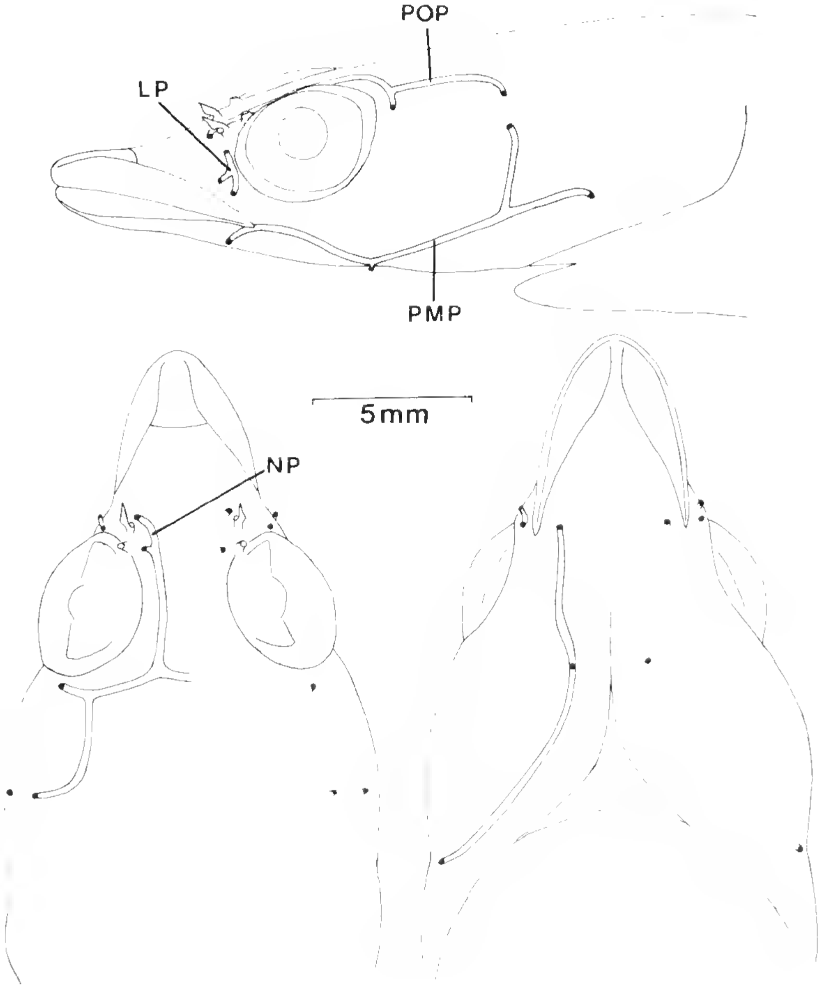

Figure 1 Diagram of the cephalic pore system of *Aspasmogaster occidentalis* sp. nov., WAM P.25774-008, 55 mm SL (pores represented by black dots, the underlying canals on one side outlined by solid lines), lateral, dorsal and ventral views. (Abbreviations: LP, lacrymal pore canal; NP, nasal pore canal; PMP, preoperculomandibular pore canal; POP, postocular pore canal.)

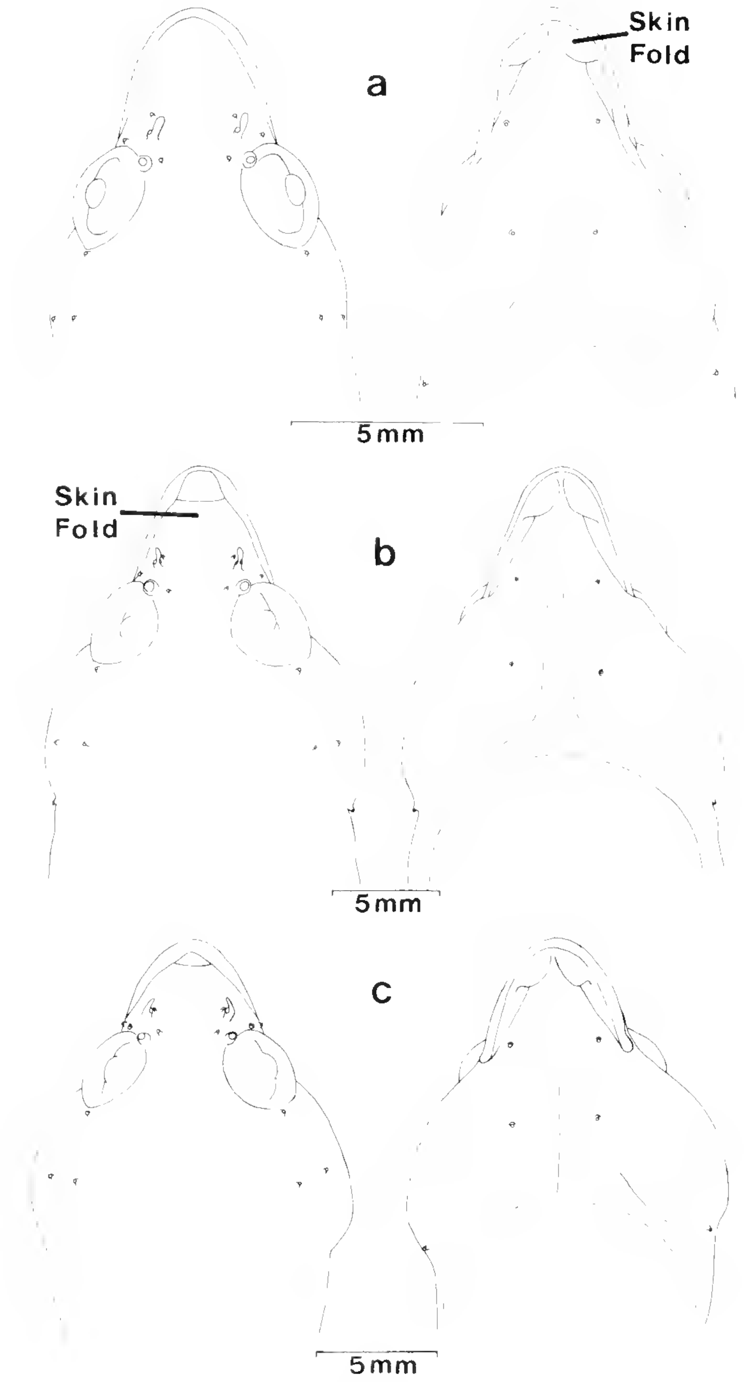

Figure 2 Dorsal and ventral view diagrams of the heads of three species of *Aspasmogaster* showing skin folds on the snouts and lower lips: (a) *A. liorhynchus*, WAM P.27569-020, 34 mm SL; (b) *A. tasmaniensis*, WAM P.27580-005, 60 mm SL; (c) *A. costatus*, NMV A.2997, 42 mm SL.

Figure 3 *Aspasmogaster occidentalis* sp. nov., holotype, WAM P.27882-001, 66 mm SL, lateral and dorsal views.

Gill opening wide, membranes joined across isthmus but not attached to it, upper attachment of gill membrane opposite second (1st-2nd) pectoral fin ray; upper attachment of pelvic fin membrane opposite seventeenth (16th-18th) pectoral fin ray; upper attachment of axial dermal flap opposite twelfth (11th-15th) pectoral fin ray; ventral disc double, moderately large in size, length 3.9 (3.7-4.4) and width 4.4 (4.6-5.4), both in SL; disc papillae arranged as in Figure 4, those in peripheral series usually increasing in number with increasing SL.

Mouth terminal, upper lip projecting a little forward of lower lip; lips large, the lower without a prominent fold anteriorly on each side (compare Figures 1 and 2); teeth in both jaws conical and posteriorly curved; lateral teeth uniserial and moderately large, enclosing anteriorly a patch of smaller teeth on each side of symphysis; palatine and vomerine teeth absent; three gills on each side; second gill arch with 11 short slender gill rakers.

Bases of dorsal and anal fins short, that of dorsal somewhat longer than and originating slightly more anterior to that of anal fin; snout to origin of dorsal fin 1.3 (1.3-1.4) in SL.

Subopercular element present, forming terminal bone posteriorly on side of head, but not spine-like; dorsal postcleithral bone reaches as high as twelfth pectoral fin ray; ventral postcleithral bones shaped as in Figure 5a, with a bone fragment near posterior edge of each element.

Colour of holotype in alcohol: head, body and fins a pale pinkish-brown, the ventral surface more whitish; upper lip and anterior rim of eye more reddish. The paratypes are similarly coloured although some have faded to an overall pale brown.

Colour when fresh (based on colour transparencies of freshly collected material): ground colour pale yellowish-brown to pale pinkish-brown, occasionally dusky brown; adults generally possess many small brown to orange spots on snout, lips and dorsal surface of head (those behind orbital region become progressively more indistinct posteriorly); very small juveniles usually have large reddish-brown blotches which tend to form cross-bands on the back,these fading in larger individuals, and also possess orange lines across dorsal surface of head and body which break up into spots with age; juveniles with a dark stripe on each side of snout adjacent to the lip.

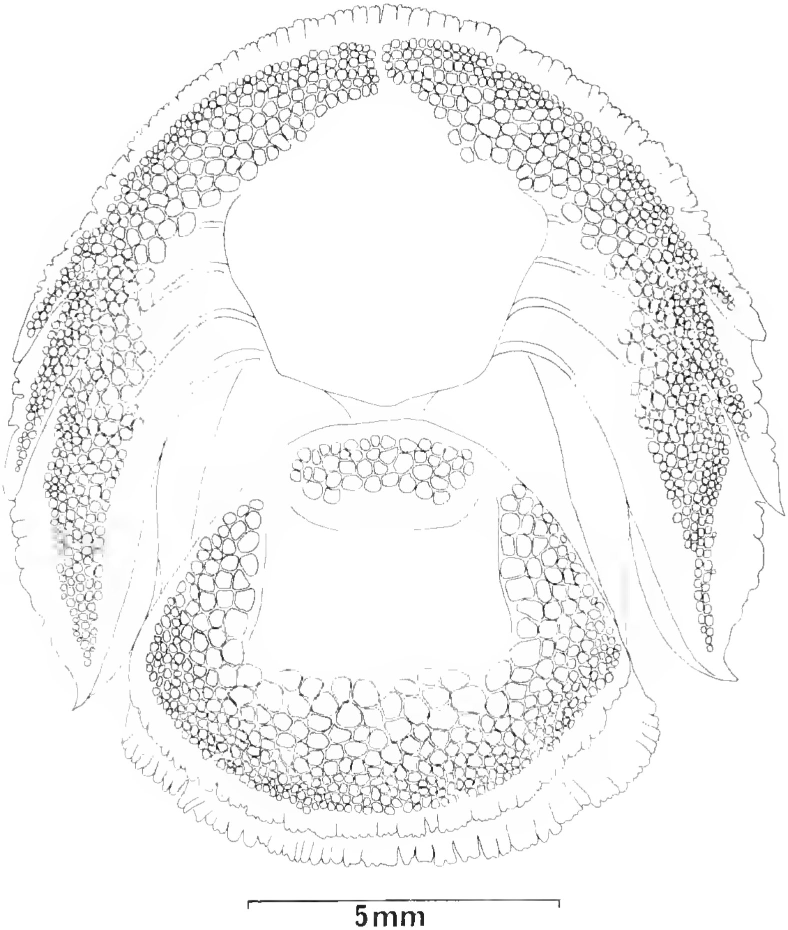

Figure 4 Ventral sucking disc of *Aspasmogaster occidentalis* sp. nov., WAM P.25774-008, 55 mm SL, showing arrangement of papillae (anterior end faces top of page).

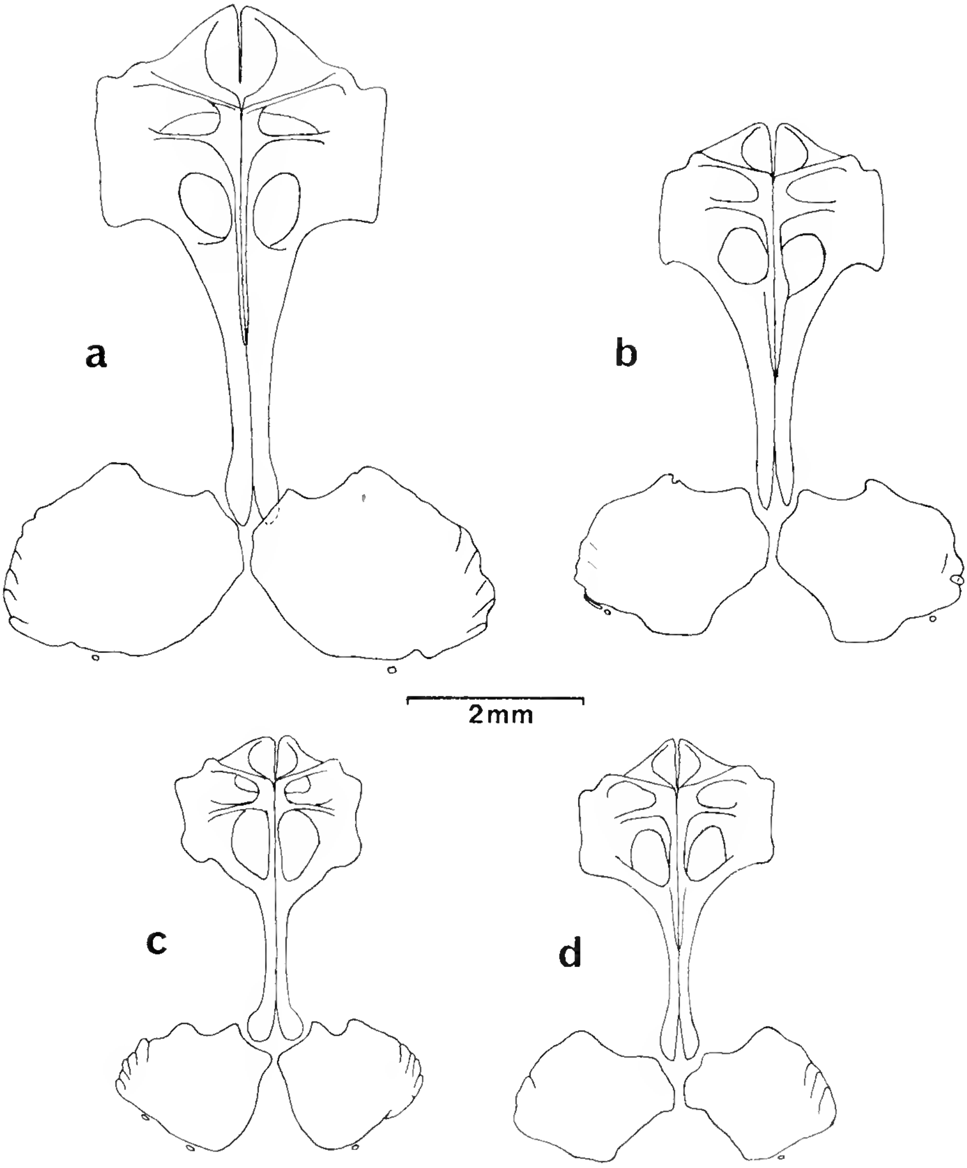

Figure 5 Pelvic and ventral postcleithral bones (ventral view) of (a) *Aspasmogaster occidentalis* sp. nov., WAM P.25770-022, 52 mm SL, (b) *A. tasmaniensis*, WAM P.27559-004, 43 mm SL; (c) *A. liorhynchus*, WAM P.26009-023, 34 mm SL, and (d) *A. costatus*, WAM P.27073-004, 34 mm SL (anterior ends face top of page).

Distribution

Aspasmogaster occidentalis is known only from Western Australia, ranging from the Archipelago of the Recherche (34°08′S, 122°15′E) to Port Denison (29°16′S, 114°55′E).

Remarks

Aspasmogaster occidentalis has been collected with rotenone from rocky bottoms at depths between 0.5 and 13 m, usually in association with *A. tasmaniensis* and/or *A. liorhynchus*. However, because of their similar overall morphology and the intraspecific variablity of colour patterns, the three are easily confused. They can be readily distinguished by careful examination of the snout for the presence or absence of dorsal and ventral skin folds (see Key to Species). Based on ventral disc papillae patterns, overall head and body morphology and the shapes of the pelvises and postcleithral bones (Figure 5), *A. occidentalis* appears to be most closely related to *A. tasmaniensis*.

This species is named *occidentalis* with respect to its geographical distribution.

Additional Material Examined

(unless otherwise designated, all at WAM)

Aspasmogaster costatus, 20 specimens from New South Wales, 9.8-51 mm SL: P.27073-004, 3 specimens, 22-34 mm SL (largest cleared and stained), Julian Rocks, Byron Bay, 20 December 1980; P.27079-003, 20 mm SL (cleared and stained), North West Solitary Island, off Arrawarra, 26 December 1980; P.27082-003, 19 mm SL, North West Solitary Island, 29 December 1980; P.27109-003, 4 specimens, 22-34 mm SL, Bowen Island, Jervis Bay, 8 February 1981; P.27112-002, 3 specimens, 19-37 mm SL (24 mm specimen cleared and stained), Summercloud Bay, south of Jervis Bay, 9 February 1981; AM B.7140, holotype, 51 mm SL, Port Jackson, June 1885; AM B.7141, paratype, 46 mm SL, apparently collected with holotype; AM IB.3641, 42 mm SL, Long Reef, north of Sydney Harbour, 6 September 1956; AM IB.3642, 32 mm SL, collected with previous specimen; AM I.15352-003, 41 mm SL, Bottle and Glass Rocks, Sydney Harbour, 23 October 1968; AM I.19504-001, 9.8 mm SL, Long Reef, 28 August 1976; AM I.23612-002, 24 mm SL, Coogee, December 1921 (removed from AM I.23612-001, paratypes of *A. liorhynchus*); NMV A.2997, 2 specimens, 33-42 mm SL, Montague Island, 15 September 1981.

Aspasmogaster liorhynchus, 41 specimens, 15-41 mm SL. New South Wales: AM IA.695, holotype, 41 mm SL, Coogee, December 1921; AM I.23612-001, paratypes, 7 specimens, 25-39 mm SL, collected with holotype (Briggs 1955: 51, listed 8 specimens [as AM IA.695] in this lot of paratypes, however one of these is *A. costatus* and has thus been removed, see AM I.23612-002).

Victoria: P.27123-015, 34 mm SL, Norman Point, Wilsons Promontory, 25 February 1981; P.27125-014, 3 specimens, 31-36 mm SL, Norman Island, Wilsons Promontory, 27 February 1981; NMV A.2367, 39 mm SL, Oberon Bay, Wilsons Promontory, 6 February 1982; NMV A.2558, 4 specimens, 27-36 mm SL, Leonard Bay, 20 February 1982; NMV A.2998, 2 specimens, 18-35 mm SL, Merricks, Western Port, no other data.

Tasmania: P.27560-014, 5 specimens, 25-32 mm SL, Sanderson Rocks, east of Bridport, 27 February 1982; P.27564-015, 2 specimens, 31-34 mm SL, East Sandy Point, north of Bridport, 3 March 1982; P.27569-020, 4 specimens, 31-39 mm SL, Rocky Cape, 9 March 1982.

South Australia: P.27136-017, 33 mm SL, West Island, Victor Harbour, 28 March 1981; SAM F.3847, 36 mm SL, Cape Elizabeth, no other data; SAM F.4669, 31 mm SL, Port McDonnell, November 1969; SAM F.4709, 37 mm SL, St Vincents and Spencer Gulfs, 11 November 1919.

Western Australia: P.26000-026, 2 specimens, 15 mm SL, Lucky Bay, east of Esperance, 12 March 1978; P.26001-005, 2 specimens, 31-33 mm SL, Lucky Bay, 13 March 1978; P.26008-009, 19 mm SL, Mondrain Island, Archipelago of the Recherche, 21 March 1978; P.26009-

023, 34 mm SL (cleared and stained), Lucky Bay, 22 March 1978; AM I.20219-028, 2 specimens, 33-36 mm SL, Rob Island (off Lucky Bay), 20 March 1978.

Aspasmogaster tasmaniensis, 70 specimens, 13-67 mm SL. Victoria: P.27119-012, 36 mm SL, Mallacoota, 20 February 1981; P.27123-004, 2 specimens, 41-51 mm SL, Norman Point, Wilsons Promontory, 25 February 1981; P.27125-001, 2 specimens, 42-64 mm SL, Norman Island, Wilsons Promontory, 27 February 1981; AM I.19248-003, 47 mm SL, Portsea Pier, Port Phillip Bay, 16 June 1976; AM I.19776-006, 62 mm SL, Flinders, Western Port, 13 April 1977; AM I.21977-001, 57 mm SL, Flinders, Western Port, 16 June 1977; NMV A.2999, 8 specimens, 45-68 mm SL, Beaumaris, Port Phillip Bay, 9 June 1967; NMV A.3000, 3 specimens, 51-60 mm SL, Beaumaris, 26 June 1967.

Tasmania: P.27547-001, 25 mm SL, Hope Island, Port Esperance, 10 February 1982; P.27549-001, 2 specimens, 47-48 mm SL, Point Puer, Port Arthur, 14 February 1982; P.27554-019, 51 mm SL, Spring Bay, 20 February 1982; P.27555-002, 2 specimens, 44-45 mm SL, Skeleton Bay, St Helens, 24 February 1982; P.27559-004, 2 specimens, 13-43 mm SL (larger cleared and stained), St Helens Point, 25 February 1982; P.27564-004, 40 mm SL, East Sandy Point, north of Bridport, 3 March 1982; P.27568-001, 47 mm SL, Boat Harbour, 8 March 1982; P.27569-001, 1 specimen 47 mm SL, Rocky Cape, 9 March 1982; P.27580-005, 2 specimens, 33-60 mm SL, Low Head, 21 March 1982; AM I.17545-011, 50 mm SL, Eaglehawk Neck, 29 November 1972; AM I.20085-001, 45 mm SL, Mills Reef, Bruny Island, 14 December 1977; QVM 1979/5/134, 11 specimens, 21-52 mm SL, north of Greens Beach, mouth of Tamar River, 21 April 1976.

South Australia: P.27136-001, 30 mm SL, West Island, Victor Harbour, 28 March 1981; AM I.20160-025, 3 specimens, 53-59 mm SL, West River Cove, Kangaroo Island, 3 March 1978; SAM F.1453, 32 mm SL, Victor Harbour, 4 March 1930; SAM F.2788, holotype of *Aspasmogaster patella* Scott, 1954, 55 mm SL, Kingston Park, 26 September 1953; SAM F.2789, 3 specimens, 49-60 mm SL, taken with previous specimen; SAM F.2935, 39 mm SL, Cape Jervois, 6 November 1956; SAM F.3624, 33 mm SL, Goose Island, 23 September 1971; SAM F.3669, 52 mm SL, Rapid Bay Jetty, 27 February 1972; SAM F.3842, 49 mm SL, Edithburgh, Yorke Peninsula, no other data; SAM F.4223, 47 mm SL, Glenelg Beach, 27 December 1975; SAM F.4393, 20 mm SL, Marion Bay, Yorke Peninsula, 28 January 1979.

Western Australia: P.4897, 2 specimens, 42-46 mm SL, Bunker Bay, 29 December 1957; P.15874, 66 mm SL, Cape Naturaliste, 29 December 1967; P.25149-001, 57 mm SL, Doubtful Island, east of Albany, January 1975; P.25195-023, 2 specimens, 21-67 mm SL, Bunker Bay, 16 December 1974; P.25770-014, 33 mm SL (cleared and stained), Sandy Hook Island, Archipelago of the Recherche, 11 April 1977; AM IA.677, 2 specimens, 19-21 mm SL, syntypes types of *Volgiolus interorbitalis* Whitley, 1943, Albany, 15 November 1921.

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Bionomics of a Pollen-collecting Wasp, *Paragia tricolor* (Hymenoptera: Vespidae: Masarinae), in Western Australia

Terry F. Houston*

Abstract

At a perennial nest-site 40 km north-east of Perth, females of *Paragia tricolor* nested for about one month in late summer/early autumn while males patrolled bushes nearby. The nests in clayey soil were characterized by mud entrance turrets, vertical shafts and horizontal cells whose cemented earthen walls were polished and waterproof internally. Each cell received a loose egg prior to being mass-provisioned with a loaf of pollen-nectar mixture and plugged with mud. *Eucalyptus calophylla* was the sole food source. Shafts of completed nests had blind diverticulae and were sealed with mud partitions. Mature larvae spun cocoons, defaecated and entered diapause. Depredators associated with nests were a wasp, *Carinafoenus* sp. (Gastcruptiidae), and a mite, *Tyrolichus casei* (Acaridae).

Some distant populations of *P. tricolor* became active in December or January and fed at another *Eucalyptus* species.

Introduction

The vespid subfamily Masarinae (*sensu* Carpenter 1982) occurs world-wide and, although very incompletely studied, is notable in that those species whose habits are known provision their nests with pollen and nectar, much as do the bees. An overview of the biology of Masarinae may be obtained from the works of Richards (1962), Malyshev (1968), Torchio (1970), Zucchi *et al.* (1976), Gess and Gess (1980) and Dorr and Neff (1982).

In Australia, the subfamily is represented by four endemic genera whose habits remain largely unknown. Wilson (1869) recorded females of '*Paragia tricolor*', later identified as *P. smithii* de Saussure (Richards 1962: 28), entering ground burrows with earth 'chimneys' in South Australia but revealed nothing of the nests' subterranean structure or contents. Riek (1970) commented that the food of Australian species is unknown and noted several plant genera whose flowers they frequent. Richards (1968) recorded *Goodenia cycloptera* R. Br. as a forage plant of two *Riekia* species.

The present paper results from the fortuitous discovery by Mr Eric McCrum of a nest colony of *P. tricolor* Smith near Perth and is the first detailed account of the biology of an Australian masarine.

Specimens collected during the course of this study are lodged in the Western Australian Museum, Perth (WAM).

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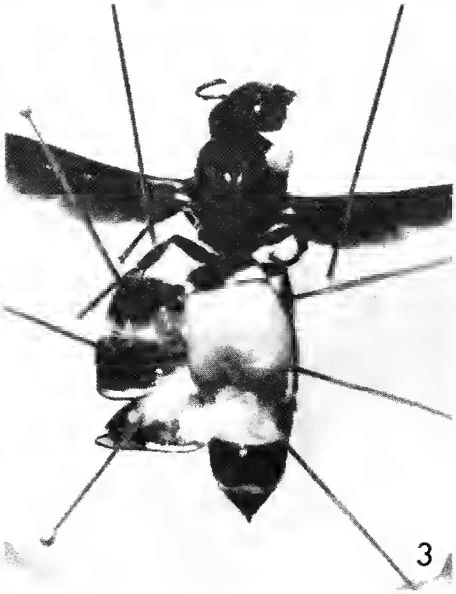


Figures 1-3 *Paragia tricolor*: (1) nest area at Noble Falls, W.A. (nests occurred in grassy area arrowed); (2) female emerging from nest turret carrying soil pellet in mandibles; (3) female dissected to show pollen-filled crop.

Observations

Nesting Site

The nest aggregation studied was at Noble Falls on Wooroloo Brook, about 40 km north-east of Perth. The nests were in an area of gently sloping, lightly grassed soil at the edge of a granite exposure and only a few metres from the perennial stream (Figure 1). The surface soil was a compacted loam which gave way at 20-30 cm depth to a hard sandy clay. Bordering the open ground were various shrubs, mostly *Acacia* species. The site was in dry sclerophyll forest dominated by *Eucalyptus calophylla* R. Br. and adjacent to cleared farmland where this same species occurred more sparsely. It was on a north-facing slope which received full sun most of the day. A strand line of flood debris occurred along the lower margin of the nesting area when first found but the area would not be inundated except in periods of abnormally high flooding.

Seasonality

Mr McCrum discovered the nesting site on 24 April 1982 when a single female entered a turreted burrow. Eight other turrets were located over an area of about 2 m^2. No live adults were observed when I visited the site on 8 May 1982 but seven nests were located by their turrets and excavated. Most had been abandoned while incomplete and five of six brood cells taken contained mouldy provisions and immature larvae. One contained a mature larva in a cocoon. Possibly nesting had been disrupted by earlier heavy rains.

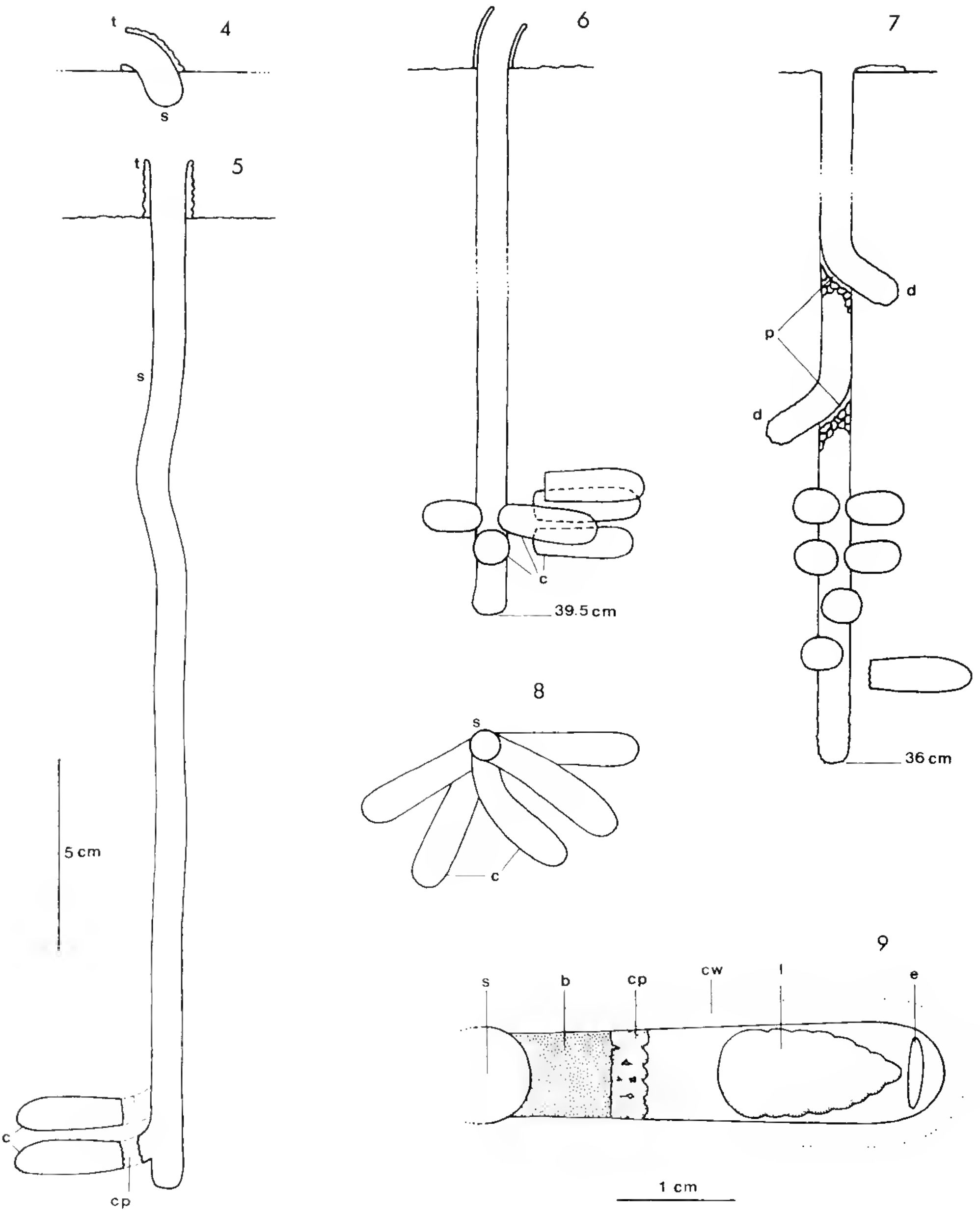
The Noble Falls site was revisited on 18 December 1982 and 13 February 1983 to check for activity but adults and turrets were absent. On 8 March 1983, adults of both sexes were active and nesting was well-advanced. Twelve turrets were found in the same ground occupied in 1982 and most were visited by females. Three nests (two active and one old and vacated) were excavated on 8 and 11 March. The active nests contained freshly provisioned cells with eggs and immature larvae. On 30 March, three closed nests containing mature larvae in cocoons were excavated, no adults were present and most turrets were collapsed (probably by rain).

All visits to the study site were made on days with fine, sunny, warm to hot weather, considered conducive to flight. Evidently *P. tricolor* produced a single generation of adults over twelve months at Noble Falls with emergence occurring in late February and activity ceasing by late March.

The foregoing observations and dates on several WAM specimens suggest that adult activity in the Darling Range-Perth region is confined to the months February-April. However, records from further north (Mullewa-Perenjori region) and further east (Coolgardie-Norseman region) indicate that activity there occurs in December and January.

Nests

Thirteen nests in various stages of development were excavated on 8 May 1982 and 8-30 March 1983. All active and recently completed nests, including some



Figures 4-9 Details of nests of *Paragia tricolor*: (4-7) profiles of nests in various stages of completion (schematic; turrets and shafts shown in section, cell chambers in outline; portions of shafts omitted from 6 and 7; measurements indicate depths): (4) early stage of excavation; (5-6) cell construction stage; (7) sealed and complete; (8) plan view of cell group depicted in 6 with closures omitted to show connections to shaft; (9) horizontal section through newly completed cell showing pollen loaf and egg (top views). 4-8 to same scale. Legend: b, barricade; c, cell(s); cp, cell plug; cw, cemented wall; d, diverticulum; e, egg; l, pollen loaf; p, partition; s, shaft; t, turret.

with shafts only a centimetre or so deep, had entrance turrets. Evidently, turrets are constructed in the initial stages of burrow excavation. Most turrets were situated amongst low dry grass and herbs and were vertical to moderately curved (Figures 2, 4-6). A few reclined on to the surface of bare ground and opened horizontally. Several occurred beneath the edges of tussocks and shrubs. Their height (or length) ranged from 15-30 mm. Internally, they were smooth and about 9.5 mm in diameter, while externally they varied from smooth to coarsely granular and were 11-14 mm in diameter. Tumuli were absent and only a few pellets of earth lay about the turrets.

Shafts were uniformly circular in cross-section, about 8.5 mm in diameter, and extended more or less vertically below the turrets. Their walls were not specially formed except in the lower extremities adjacent to the brood cells. Where cells were present, shafts varied in depth from 20-40 cm.

Nests under construction contained 1-6 cells, three recently completed nests contained 3, 7 and 8 cells, and an old vacated nest contained 14 (Figures 5-7, 16). Cells occurred at depths of 19-38 cm, mostly in the loam-clay interzone which was quite dry at the time of excavation. They were usually confined to one side of the shaft (Figure 8) and were sometimes in contact with one another.

Each cell was a horizontal, somewhat cylindrical chamber apparently connecting directly with the shaft. However, its 'throat' probably represents an extremely short access burrow. Cells (including access burrows) were 24-42 mm long and attained their maximum diameters of 8.5-9.5 mm near their rounded blind ends. They tapered gradually into their throats which were 1-2 mm narrower (Figure 9). The walls of cells were of cemented earth and about 2 mm thick. Whether these were built-in or formed by impregnation of the walls of excavated cavities was not clear, but some walls appeared darker than the yellow clay matrix. Their hardness permitted cells to be removed intact (Figure 15) after scraping away the softer matrix but they had no discrete external surfaces.

Internally, cell walls were very smooth, shiny and light chocolate brown. The gloss diminished towards the cell mouth (Figure 10). That the inner walls were waterproof was demonstrated when drops of water placed on them remained unabsorbed whereas others placed on the outsides were absorbed immediately. Microscopic examination revealed no special film or coating on the inner walls. A piece of cell wall soaked in water gradually disintegrated, the outer layers slumping first and the fine clay inner surface resisting longest. One complete, closed but unprovisioned cell exhibited a scaly pattern on its inner walls suggesting that they had been deposited as pellets 0.5-1.0 mm wide.

Following oviposition and provisioning, each cell was closed with a plug of cemented earth up to 10 mm thick. Plugs consisted of an inner partition (the cell plug proper), showing a concentric pattern of pellets on its rough inner surface, and a barricade of compacted soil (the access burrow filling) plastered smooth and flush with the shaft walls externally (Figure 9). Thus, cells were undetectable from within the shafts. Where several cells had been sealed, the shaft walls were largely built-in and slightly glazed.

On 30 March, two nests with sealed shafts were excavated. In both, the shaft had two blind diverticulae closed from the shaft below by cemented partitions (Figure 7). The latter were built upon plugs of mud pellets and were smooth and moulded so as to maintain the contours of the shaft into the diverticulae. Presumably they were constructed with soil excavated from the diverticulae. In one of these nests there was also a rough-walled lateral burrow below the cells.

Remains of old vacated nests were frequently encountered while excavating and were sometimes in very close proximity to new nests. One new shaft ran parallel to an old one with only 2-3 mm separation.

Provisions

Ten closed cells with fresh or partly consumed provisions were examined on 8 and 11 March 1983. In each case, the provisions consisted of a loaf of soft, moist, yellow pollen, wide enough at the cell plug end to almost occlude the cell lumen and tapering to the other end (Figures 9-12). The loaves had folds and annulations which probably represented successive deposits of food. This suggested that a female first deposits food in the median line of the floor near the cell base and subsequently alternates regurgitations to the left and right towards the cell mouth. Loaves varied considerably in size (lengths 16-24 mm) independently of cell size. They tasted sweet indicating that the pollen was moistened with nectar. Some loaves taken to the laboratory began to develop vesicles over their surfaces within a day suggesting that fermentation was occurring. This ceased as they dried.

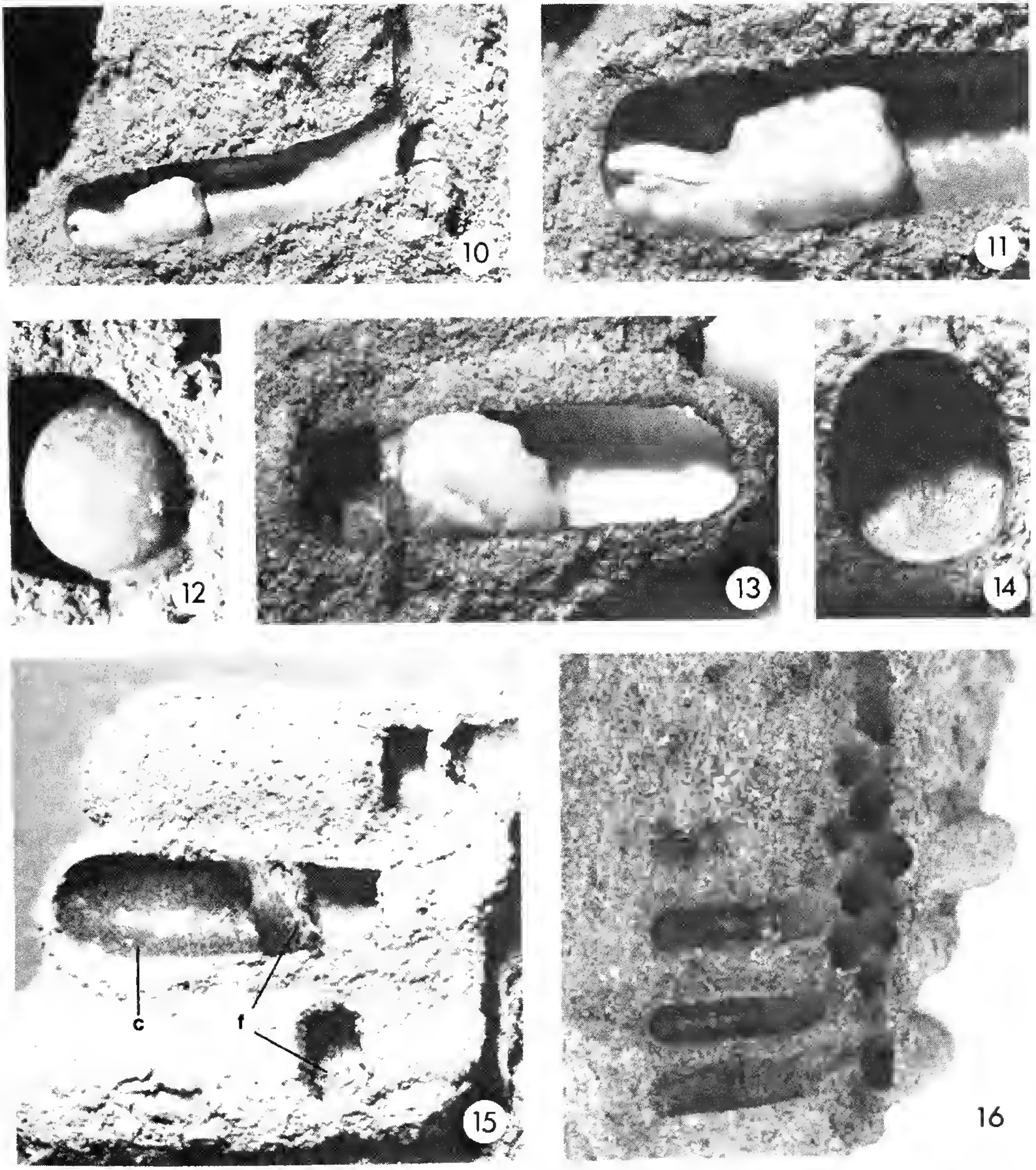
A female captured returning to her nest in which there were freshly provisioned cells was dissected and it was found that her pollen-filled crop occupied about two-thirds the volume of her abdomen (Figure 3). A full load would be equivalent to several folds in a pollen loaf.

Samples from all ten pollen loaves were examined microscopically and consisted entirely of one kind of myrtaceous pollen matching that of *Eucalyptus calophylla.*

Immatures

In each of two newly completed closed cells, a large (6.2 mm long, 1.4 mm wide), fusiform egg lay transversely and loosely in the inner end behind the pollen loaf (Figure 9). The eggs must have been deposited prior to commencement of provisioning as the females could not have got past the pollen loaves.

In other cells, small to medium-sized larvae fed at the tapered inner ends of pollen loaves (Figures 10, 11). All mature larvae found were enclosed in cocoons which were evidently constructed after completion of feeding and prior to defaecation. The cocoons consisted of a black to brown papery material closely applied to and not readily separable from the inner ends of cells. The inner end of each



Figures 10-16 *Paragia tricolor*: (10-11) cell opened from side to show young larva feeding on pollen loaf; (12) outer end of a pollen loaf; (13) cell with cocoon opened from side to show mature larva in resting position; (14) outer view of cocoon septum; (15) group of three cells partly opened to show faeces (f) and cocoon (c) of *Carinafoenus* sp.; (16) old vacated nest with fourteen cells exposed from the sides.

was rounded in conformity with the cell base, and the outer end was truncate and formed by a flat, circularly-striate septum (Figures 13, 14). A space up to 10 mm long remained between this septum and the cell plug. Cocoons varied in length from 17-24 mm. Silk strands were far more numerous in their walls nearest the septum than in the much thinner, more fragile walls of the inner end.

Black faecal material was deposited as a thin layer over the inner three-fifths or so of each cocoon and often also as thick scales at the inner end. This faecal layer was covered with white mould in numerous cocoons in recently completed nests (Figure 13).

All mature larvae were found immobile and unresponsive, pressed against the flat septa of their cocoons and out of contact with the faecal layers (Figure 13). Each rested with its head and forebody reflexed ventrally and its broad soft body occluding the cocoon lumen.

Associated Organisms

Two kinds of depredators were found in association with nests: a parasitoid wasp, *Carinafoenus* sp. (Gasteruptiidae), and a mite, *Tyrolichus casei* Oudemans (Acaridae).

Both sexes of *Carinafoenus* sp. were observed over the nesting area on 8 and 11 March 1983. The wholly orange-bodied wasps (21-23 mm long) were conspicuous as they hovered persistently to and fro throughout the day. Up to six were present at a time. Although none was seen to enter or leave a turret or pay particular attention to one, gasteruptiid larvae were found in three cells. One immature larva was found on a mouldy pollen loaf. Two mature larvae were found in their cocoons in cells. They differed conspicuously from the host larvae in being more slender, setose and active. Their cocoons were distinctive in having masses of black rod-like faeces outside the septa (Figure 15) and the septa were blacker and concave internally. Evidently, the larvae of *Carinafoenus* develop on the pollen stores, probably after destruction of the *Paragia* eggs.

Mites were found only in one cell where dozens of eggs and nymphs and several adults of *T. casei* occurred on a dried, shrunken pollen loaf. No *P. tricolor* immature was present. *T. casei* is a cosmopolitan pest of stored products (cheese, grain, flour and old honeycomb) and is not recorded as a close associate of Hymenoptera (A. Fain pers. comm.).

Adult Behaviour

Females returning to their burrows from foraging trips hovered in hesitantly and alighted either on the ground or on the rims of their turrets before entering them head first. They always reversed out of the turrets, indicating their inability to turn within the burrows. Nest-building was not observed except that a female was noted carrying a pellet of soil in her mandibles as she emerged from a turret (Figure 2) and returning without it after a brief flight. Clearly, most soil excavated must be carried well away from the burrows as no more than a few pellets lay around turrets.

On two observation days (8 and 11 March), up to ten males were in flight near the nesting area at any one time between about 8.30 a.m. and 2 p.m. They flew fairly quietly (except for a few with very ragged wings) and were very attentive to several shrubs without flowers on the margin of the nesting area. They flew erratically in and around the shrubs but seldom alighted. Territorial behaviour appeared to be absent as the flight paths of males interwove and only occasional chases were noted. One male pounced on and grappled with a female approaching her turret but copulation did not ensue. After midday the number of individuals patrolling gradually diminished until all had vanished by about 2 p.m.

Forage Plants

No adults were observed foraging at Noble Falls. However, examination of larval provisions (see above) suggested that Marri (*Eucalyptus calophylla*) was the sole source of pollen. Marri trees were virtually the only source of pollen and nectar at Noble Falls while adults were active in 1982 and 1983. In 1983, local flowering peaked in February prior to adult emergence and had almost ceased on 30 March (when activity had ended). The flowering period of Marri is recorded as February and March (Beard 1970) but irregular flowering earlier or later is not uncommon. Thus, the activity season of *P. tricolor* in the Darling Ranges coincides approximately with the flowering period of this plant.

Marri does not occur at all *P. tricolor* localities and on 20 January 1982 at Dedari (near Coolgardie) I collected 14 male and 2 female *P. tricolor* at flowers of White Mallee (*Eucalyptus cylindriflora* Maiden and Blakely). Probably the observed regional differences in activity periods (see Seasonality) are correlated with flowering times of different forage plants.

Discussion

Detailed comparison of the ethology of the Masarinae so far studied is hampered by insufficiency of data in some reports. However, it is clear that *P. tricolor* conforms generally to the pattern of behaviour described for most species and particularly for those members of the ground-nesting genera *Ceramius, Jugurtia* and *Trimeria* (Masarini). Some other Masarini (*Masaris, Pseudomasaris* and *Celonites*) differ radically from these genera in building aerial mud nests or nests in beetle burrows in logs.

The ground-nesters conform in nesting in hard clayey soil near water (which is required to produce mud) and in constructing entrance turrets, vertical shafts and separate earthen cells at the ends of lateral burrows (sometimes very reduced, as in *P. tricolor*). Eggs are deposited loosely in cells (unlike those of Gayellini which are attached by threads to the cell walls) and before the cells are provisioned with annulated loaves of moist pollen.

Some ground-nesters (e.g. *Ceramius capicola* Brauns and *C. lichtensteinii* [Klug]) construct bulbous enlargements of their shafts used by the wasps for turning whereas others, including *P. tricolor,* do not. Also, some (such as *C. lichtensteinii, C. tuberculifer* Saussure and *Jugurtia confusa* Richards) construct mud cells within excavated chambers while others form only excavated cells. The method of cell construction employed by *P. tricolor* merits further attention as this study failed to determine whether the 2 mm thick mud walls of cells were built-in or formed by impregnation of the walls of excavated chambers by some cementing liquid. No roughed-out or obviously incomplete cells were discovered that might have shed light on this problem.

A polished inner cell wall, as occurs in *P. tricolor,* has been reported for *Trimeria howardii* Bertoni (Zucchi *et al.* 1976). In other genera, the walls are smooth but dull and, as with *Trimeria,* their water absorbency has not been reported. No explanation was obtained of how females of *P. tricolor* produce the lustrous and waterproof inner surfaces of their cells.

The shaft closures of *P. tricolor* have no known parallel amongst their ground-nesting relatives. Not only may the oblique mud septa serve as barriers to potential depredators but they may also deflect them into the diverticulae where (should they attempt to burrow deeper) they would expend their energies fruitlessly.

According to Richards (1962), the closest relatives of *Paragia* are the other Australian masarine genera about whose nesting habits nothing has been published. However, I have observed a female of *Rolandia maculata* (Meade-Waldo) and one of an undescribed *Riekia* species entering burrows in sandy ground. Both burrows were simple, oblique and ended blindly without any cells and neither had an entrance turret.

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Biological Observations of Bees in the Genus *Ctenocolletes* (Hymenoptera: Stenotritidae)

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Abstract

Ctenocolletes consists of chiefly vernal species which forage at plants in several families. Some species appear to prefer particular kinds of nectar and pollen but not necessarily of the same plant genera.

Males either patrol flowers in search of females or (in *C. smaragdinus*) hover in territories near flowers. Prolonged mating and conjugate flight were observed in three species. In *C. smaragdinus* and *C. tigris,* females mounted by males continued to forage and some gathered full loads of pollen.

Two roosting aggregations of *smaragdinus* males were observed to disperse in the mornings and re-form each evening at fixed sites on foliage. Males of *C. tigris* roosted solitarily.

Nests of *C. ordensis* were found loosely aggregated in level ground and each was tended by a single female. Details of the site, nest architecture, provisions, adult activity at nests and associated organisms are provided. Features of nests were their entrance pit and complex cell closure which incorporated a pair of 'false cell-base' partitions. Nests were frequented by gasteruptiid wasps of the genera *Crassifoenus* and *Hyptiogaster.*

Adults of *C. centralis, C. nicholsoni* and *C. tricolor* frequently carry hypopial mites (Acarina: Acaridae). On females the hypopi are normally secreted in unusual cavities beneath the lateral portions of two metasomal terga. *Triungulins* (Coleoptera: Meloidae) were found attached to adults.

Introduction

This paper presents the first observations of the habits of bees in the primarily Western Australian genus *Ctenocolletes* Cockerell and adds significantly to our meagre knowledge of the biology of Stenotritidae as a whole. Previously, the only detailed behavioural information available for this small endemic Australian family concerned *Stenotritus pubescens* (Smith) and some of its congeners (Houston 1975). More information has been eagerly awaited in the hope that it might help elucidate the affinities of stenotritids whose place in the taxonomic hierarchy of Apoidea has long been subject to doubt.

The taxonomy of *Ctenocolletes* (at genus and species levels) has been dealt with by Houston (1983*a, b*).

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Observations and Discussion

Seasonality

Judging from collection data (Houston 1983*a, b*), *Ctenocolletes* are predominantly univoltine vernal bees. More northerly species such as *C. centralis* Houston and *C. nicholsoni* (Cockerell) may make their first appearance in July while more southerly ones such as *C. smaragdinus* (Smith) and *C. tricolor* Houston do not appear until September. The period of adult activity appears to be only about one month in *C. nicholsoni* but may extend over four months in *C. rufescens* Houston. The latter inhabits a far greater latitudinal range than the former and its activity at any one site may be shorter. Adults of *smaragdinus* have been observed at study sites from early September to late November. However, two collection records (a female in July and a male in February), if accurate, suggest that emergences may occur at other times.

A possible exception to the rule of vernal habits is *C. fulvescens* Houston which, although known only from a unique female, was collected in January.

Flower Visiting and Foraging

Plant records for museum specimens of *Ctenocolletes* are comparatively few as are field observations. Consequently only tentative conclusions may be drawn regarding preferred nectar and pollen sources. The available information is presented in Table 1.

Some additional data on pollen preferences of *C. ordensis* Michener were obtained by analysis of food masses in eleven brood cells. Six kinds of pollen were distinguished and various combinations of these occurred in all but one cell. *Cassia charlesiana* pollen was present in all samples and formed about 40-100% of each. Pollen from *Acacia, Eucalyptus* (tentatively identified) and an unidentified source formed significant portions of about half the samples. *Scaevola spinescens* grains formed a minor fraction of two samples.

From the table it may be seen that, except perhaps for *C. fulvescens,* all species forage at flowers of two or more plant families. Myrtaceae are visited by all species. Other families visited (in order of popularity) are Mimosaceae, Proteaceae, Goodeniaceae, Caesalpiniaceae, Chloanthaceae and Solanaceae. Despite the variety of food plants visited, some species exhibit apparent preferences for certain pollens: *C. albomarginatus* Michener, *C. rufescens, C. smaragdinus, C. tigris* Houston and *C. tricolor* for certain Myrtaceae; *C. centralis* and *C. nicholsoni* for *Acacia*; and *C. ordensis* for *Cassia*. However, because these species sometimes visit and collect from plants of two or more families they cannot be strictly termed oligolectic.

Clearly, females often visit two or more kinds of plant while collecting pollen and gather mixed loads. On these same trips they may frequently visit other kinds for nectar alone. One cannot assume, therefore, that pollen-laden females are necessarily carrying pollen of the plant on which they were recorded. *Verticordia,* for example, is primarily a nectar source for *C. smaragdinus* as are other myrtaceous genera for *C. nicholsoni.*

Ctenocolletes species prefer certain food plants and are not merely limited by what is available to them. For *nicholsoni, ordensis, rufescens, smaragdinus* and *tigris,* at least, there are many good nectar and pollen sources available during their activity periods that they do not utilize.

Plants visited by *Ctenocolletes* vary in form from low shrubs to small trees and display a wide range of flower colours. This applies to the food plants of some species as well as the genus as a whole. However, a common characteristic of almost all pollen sources is that the flowers are small and clustered and/or have numerous erect stamens. Pollen collecting females work feverishly, running over the flower heads and seldom remaining alighted for more than a few seconds. They hover frequently to preen and transfer pollen to the scopa and on alighting do not usually fold the wings but retract them to a V-shape. Some females of *nicholsoni* even continue to beat their wings as they scurry over *Acacia* flowers. *C. ordensis* and *C. tigris* are the only species known to collect pollen from flowers with porose vibratile anthers and do so in the manner of many other bees by hunching over the anthers and vibrating their thoracic muscles with an audible buzz. Pollen is at first accumulated dry but (at least in four species) is moistened towards the end of foraging trips and forms smooth firm masses on the outer sides of the hind tibiae and basitarsi (Figure 1).

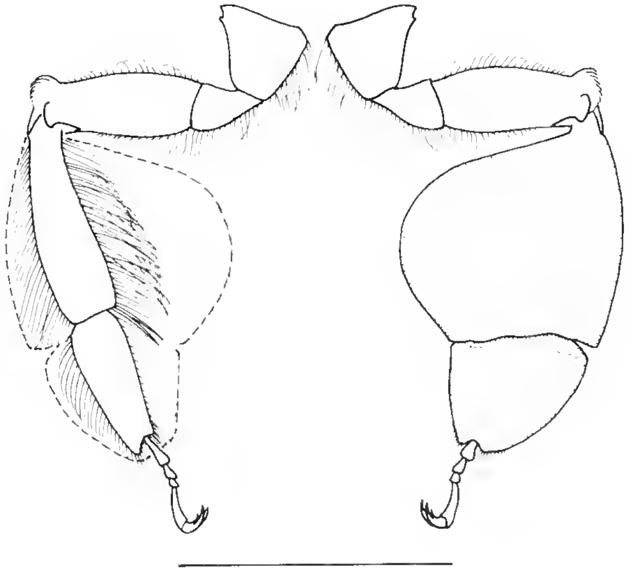


Figure 1 Hind legs of *Ctenocolletes ordensis* female (anterior view) showing full pollen load (right, stippled) in relation to tibial and basitarsal scopa (left; anterior setation omitted for simplicity). Scale line, 5 mm.

Table 1 Records of flowers visited by adults of *Ctenocolletes* and pollens carried on the scopae of females.
Sight records are distinguished by parentheses around numbers of specimens. Relative amounts of pollens in samples were estimated visually and are indicated by +, > and ≫ (e.g. in a mixture of A and B these symbols mean that A represents 45-55%, 56-70% or 71-95% respectively). Amounts less than 5% may have represented flower contaminants and are ignored. Abbreviations: M, matches pollen of plant visited; N, many; NK, not known; NM, not matching pollen of plant visited; U, U_1, U_2, etc., unidentified species.

Species	Flowers visited	No. bees	Pollens carried by females	No. ♀
C. albomarginatus	*Baeckea stowardii*	1 ♀	Myrtaceae$_1$ NM ≫ Myrtaceae$_2$ NM + U	1
	Eucalyptus oldfieldii	1 ♂		
	Hakea coriacea	1 ♂		
	Scholtzia spathulata	2 ♂		
	Wehlia thryptomenoides	2 ♀	Myrtaceae M	2
	Westringia sp.	1 ♂		
	NK	4 ♀	Myrtaceae	4
C. centralis	*Baeckea stowardii*	2 ♀	nil	2
	NK	5 ♀	*Acacia*	5
C. fulvescens	*Eucalyptus oleosa*	1 ♀	Myrtaceae M	1
C. nicholsoni	*Acacia aneura*	1 ♀	*Acacia* > *Scaevola spinescens* > *Baeckea*	1
	Acacia blakelyi	1 ♀	*Acacia*	1
	Acacia tetragonophylla	3 ♀	*Acacia*	3
	Acacia sp.	1 ♀	*Acacia*	1
	Baeckea pentagonatha	2 ♂ 6 ♀	*Acacia*	4
	Calytrix oldfieldii	1 ♂ 1 ♀	U > *Acacia* ≫ *Calytrix*	1
	Scholtzia drummondii	2 ♂ 5 ♀	nil	5
	Wehlia thryptomenoides	2 ♀	Myrtaceae M	2
	NK	10 ♀	*Acacia*	8
			Acacia ≫ Myrtaceae	1
			Myrtaceae ≫ *Acacia*	1
C. ordensis	*Cassia charlesiana*	(1 ♀)		
	Cassia chatelainiana	1 ♂		

	Scaevola spinescens	2 ♂	1 ♀	nil	1
	NK (collected at nests)		6 ♀	*Cassia charlesiana*	1
				Cassia > Myrtaceae ≫ *Acacia*	1
				Cassia + Myrtaceae ≫ *Scaevola spinescens*	1
				Cassia ≫ U_1 + *Scaevola spinescens*	2
				Scaevola spinescens > Myrtaceae + U_1	1
C. rufescens	*Eucalyptus oldfieldii*	2 ♂			
	Grevillea ?pterosperma		3 ♀	Myrtaceae NM	2
	Hakea coriacea	5 ♂			
	Melaleuca scabra		1 ♀	Myrtaceae M	1
	Melaleuca uncinata		1 ♀	Myrtaceae M	1
	Scholtzia drummondii	4 ♂			
	Scholtzia spathulata	14 ♂	1 ♀	nil	1
	Wehlia thryptomenoides		8 ♀	Myrtaceae M	4
	NK		2 ♀	Myrtaceae	1
				Myrtaceae ≫ *Acacia* + *?Grevillea*	1
C. smaragdinus	*Baeckea ?leptospermoides*		1 ♀	nil	1
	Beaufortia bracteosa		(1 ♀)		
	Grevillea biformis	(N ♂)	1 ♀	*Grevillea* M	1
	Leptospermum erubescens	1 ♂	1 ♀	nil	1
	Melaleuca leptospermoides		1 ♀	Myrtaceae M ≫ *Grevillea*	1
	Melaleuca microphylla	1 ♂	1 ♀	Myrtaceae M	1
	Melaleuca scabra		1 ♀	Myrtaceae M	1
	Verticordia chrysantha	7 ♂	(3 ♀)		
	Verticordia picta	1 ♂	3 ♀	Myrtaceae NM ≫ *Grevillea*	1
				Grevillea > Myrtaceae NM ≫ U	1
C. tigris	*Baeckea stowardii*	1 ♂	1 ♀	nil	1
	Dicrastylis exsuccosa	7 ♂ (N ♂)	4 ♀	*Dicrastylis* M	1
	Solanum sp.		1 ♀	*Solanum* > *Dicrastylis*	1
	Wehlia thryptomenoides	3 ♂ (N ♂)	3 ♀	Myrtaceae M	3
C. tricolor	*Grevillea paradoxa*	1 ♂			
	Grevillea ?pterosperma	7 ♂			
	Melaleuca scabra		1 ♀	Myrtaceae M	1
	Wehlia thryptomenoides		1 ♀	Myrtaceae M	1

The majority of food plants have exposed or readily accessible nectaries as is to be expected in view of the bees' relatively short mouth parts.

Foraging in most species occurs from mid-morning to late afternoon. However, the type specimen of *fulvescens* was collected while foraging at sunrise in very hot weather.

Because *Ctenocolletes* mainly forage at plants of characteristically Australian genera with wide distributions in this continent, the distributions of food plants alone cannot determine those of the bees.

Up to five species of *Ctenocolletes* occur together in some localities (Houston 1983*a*) and, as they are active during more or less the same period, the question arises as to whether they compete for resources. In the neighbourhood of Sandstone, one finds *centralis, nicholsoni, albomarginatus, rufescens* and *ordensis.* The last-named is unique in being largely dependent on *Cassia* for pollen. Its nectar sources are not known with certainty but probably include *Scaevola spinescens.* The first two appear to rely largely on *Acacia* pollen while the remaining two rely largely on myrtaceous pollen. Probably all four utilize myrtaceous nectar. Thus, partition of food resources is partial. However, because the shared food plants usually flower prolifically (except in periods of drought), there is not normally likely to be serious interspecific competition.

Male Patrolling and Territoriality

Males of all species but *C. fulvescens* have been observed in fast, patrolling flights over the food plants. Often their flight is so fast that the bees are heard rather than seen and they can be extremely difficult to net. Males of *C. nicholsoni* are particularly fast and noisy fliers. Males occasionally alight to take nectar but most of their time from mid-morning to late afternoon is spent in flight.

Because of their brilliant green iridescence, males of *C. smaragdinus* are easiest to identify in the field. They appear to follow fairly regular circuits passing clumps of flowering food plants over wide areas of heath. They seldom slacken their pace as they pass flowers. In open heaths their density is so low that encounters between them are few but at a bank of tall, heavily flowered *Melaleuca microphylla* shrubs, both sexes were abundant and contact between individuals was frequent. Many times males were observed to engage one another in bouts of circling and chasing.

A smaller number of *smaragdinus* males were observed in prolonged hovering flight near food plants. At the *Melaleuca* shrubs just mentioned several males hovered in gaps in the foliage at heights of 0.5 to 3.0 m above ground. For the most part they hovered almost stationary but frequently turned this way or that or moved a few centimetres. Most movement was confined to a space of about 50 cm diameter but occasional brief dashes were made to other parts of the shrub bank. In an area of low heath, several isolated males were observed hovering as low as 5 cm above ground in the lee of flowering *Melaleuca scabra* shrubs. Many similar but untended shrubs were nearby and the basis of the bees' selection was not apparent.

Despite several hours of observation at localities where males of *nicholsoni, rufescens, tigris* and *tricolor* were numerous, no instances of territoriality were found. Males of *nicholsoni* occasionally paused momentarily in hovering flight near flowers but generally their flight seemed erratic and the flight paths of numerous individuals interwove.

Mating and Conjugate Flight

The following observations of *C. smaragdinus* were made at Emu Rocks, 53 km east of Hyden, and at Boorabbin Rock, 93 km east of Southern Cross.

Initiation of mating was observed only once when a patrolling male dashed upon a female taking nectar at flowers of *Verticordia chrysantha.* The pair fell to the ground buzzing and struggled for a few seconds, then took flight conjugately, the male above the female, and flew laboriously out of sight.

Thirteen other male/female pairs of this species were observed over several days in mid-October and again (at the same locality) in mid-November; so pairing apparently occurs throughout the flight season. In all cases pairs consisted of a male mounted on the back of a female. A few of them rested on shrubbery and took flight as I brushed by. One such pair remained united when netted and even when handled. Unfortunately, the bees escaped before details of their coupling could be noted. A second disturbed pair resettled on a stem and close observation revealed that the genitalia were coupled and the male's metasoma was pulsating. The female carried no pollen and her unworn wings suggested she was newly emerged. The remaining pairs were observed on flowers. In eight of these where close inspection was possible the genitalia were definitely not coupled and three females carried pollen loads. One foraging pair was observed for 15 minutes, during which time the female gathered pollen from *Melaleuca scabra* and nectar from *Verticordia picta.* The pair settled intermittently on shrub stems while the female groomed herself and compacted her pollen load and, when the latter was moist and complete, flew rapidly out of sight.

In each pair which was closely inspected, the male gripped his partner as depicted in Figure 2. His fore tarsi gripped the bases of her wings near the tegulae, his mid legs grasped her body behind her wings and in front of her hind legs, and his hind legs wrapped around and under her metasoma. His antennae stretched forward over her thorax. When pairs took flight, both individuals beat their wings, the male apparently taking his cue from the female and probably sensing her wing vibrations through his fore tarsi. Pairs flew slower, more directly and more noisily than individuals.

Similar behaviour was observed for *C. tigris* in the Great Victoria Desert, Western Australia, in September 1982. Four pairs flying conjugately were captured at flowers of various food plants. In two cases the genitalia appeared to be coupled and the females were taking only nectar and not carrying pollen. In the others, the females carried pollen loads but the coupling was not ascertained. Conjugate pairs were not troubled by other males even at one bush attended by about eight individuals. One difference from *C. smaragdinus* was that males in pairs carried their antennae erect.

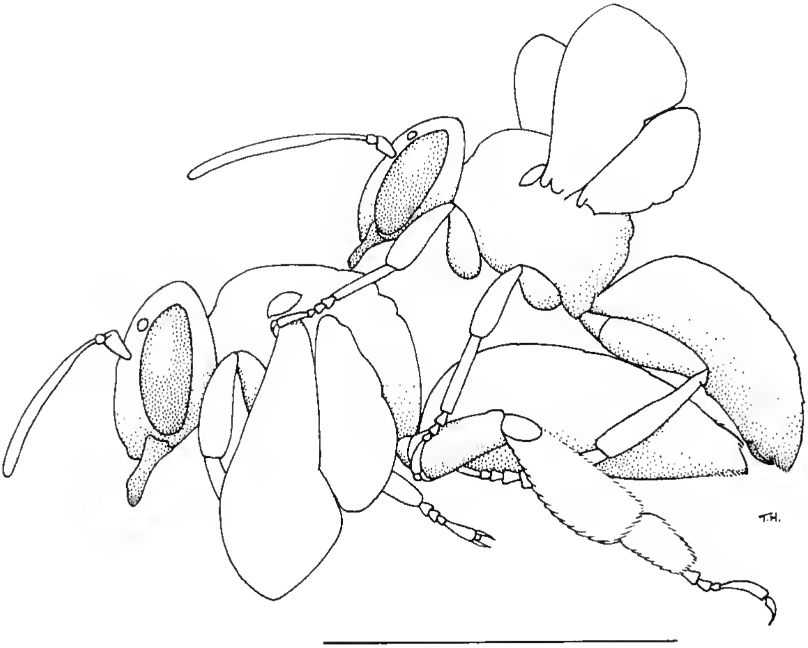


Figure 2 Sketch showing how *Ctenocolletes smaragdinus* male (above) grasps female during conjugate flight. Scale line, 1 cm.

Conjugate flight has also been observed in two other species. On 22 October 1974, about 8 km south of Yellowdine, I observed a pair of large bees hovering slowly through foliage before settling on a shrub stem. I was only able to note that a male was mounted on the back of a female before they were disturbed and flew off, still united. Males of *C. tricolor* were abundant in the near vicinity and I assumed that the pair was of this species. However, a few females of *C. rufescens* were also collected near the site. On 2 September 1981, Mr G.A. Holloway of the Australian Museum observed and collected large bees flying *in copula* near flowers of *Eucalyptus*, 28 km west of Yalgoo (pers. comm.). Two pairs of *C. ordensis* were amongst specimens collected by him on that occasion and his recollection was that they were the mating pairs (a male of *C. nicholsoni* was also collected). As mentioned later in this paper, females of *C. ordensis* arrived alone at their nests which were not frequented by males, so conjugate flight may be confined to the vicinity of food plants.

The prolonged sexual coupling and conjugate flight of *Ctenocolletes* are singular habits not observed in its sister genus *Stenotritus* despite some days of observation of several species. Conjugate flight has seldom been reported for bees. It is known in certain species of the North American genus *Nomadopsis* (Andrenidae: Panurginae) (Rozen 1958, Alcock *et al.* 1978) and the non-Australian genus *Colletes* (Colletidae: Colletinae) (Batra 1980). Behaviour of *Colletes* differs markedly from that of *Ctenocolletes*: in *C. thoracicus* Smith and *C. cunicularius* (L.), pairs engage in nuptial flights of up to 2 minutes duration but males are carried horizontally behind females, coupled by their genitalia. Coupled females are mostly newly emerged and do not forage. *Nomadopsis* behaviour is rather more similar in that males ride facing forward above females often while the latter collect full pollen loads. However, two differences are that the genitalia are always coupled and males hold their mid and hind legs out away from females.

Alcock *et al.* (1978) supposed that protraction of mating in *Nomadopsis* may serve to shield foraging females from the disruptive attentions of other males. This may be so but, at least in *Ctenocolletes,* this advantage would seem to be offset by the slowing effect male jockeys exert on their partners.

The three species of *Ctenocolletes* definitely known to fly conjugately (*ordensis, smaragdinus, tigris*) form a discrete group but my observation of similar behaviour in a more distant species (either *rufescens* or *tricolor*) suggests that conjugate flight may be a generic trait.

Male Roosting

In the second week of October 1979, on the crest of a low heath-covered rise 53 km east of Hyden, clusters of *C. smaragdinus* males were found gathering at evening in two low dense shrubs about 30 m apart. The bushes, one a *Chamaelaucium virgatum,* the other a *Casuarina* sp., were rotund, about 40 cm high and had fine foliage but neither was conspicuous amongst the surrounding vegetation. Attention was first drawn to them by males milling about in their near vicinity at 4.25 p.m. (W.S.T.). As some males arrived for a period of circling, others departed. Gradually, the number of males grew to dozens producing a hum audible many metres away. At around 5.15 p.m. males began settling and all had alighted by 6.00 p.m. (10 minutes before sunset). At 6.20 p.m. an inspection revealed three spherical clusters in one bush and a larger elongate cluster (*c.* 15 cm x 5 cm) in the other. Each bush held approximately 100 tightly packed males with their heads hidden within the groups.

At sunrise the morning after their discovery, the males were quite torpid and remained motionless when picked off into the hand. At 10.30 a.m., as the first rays of sunlight penetrated a cloud cover, only a few bees remained and these soon dispersed. Each evening the clusters re-formed in the same manner. Revisited a month later, one bush had a much diminished cluster while the other was deserted.

In September 1982, in the Great Victoria Desert, W.A., three males of *C. tigris* were found separately in torpid condition on various low shrubs at night or

Figure 3 Part of nesting area of *Ctenocolletes ordensis* on Anketell Station, W.A. Many nest entrances were in bare ground near excavation (right foreground).

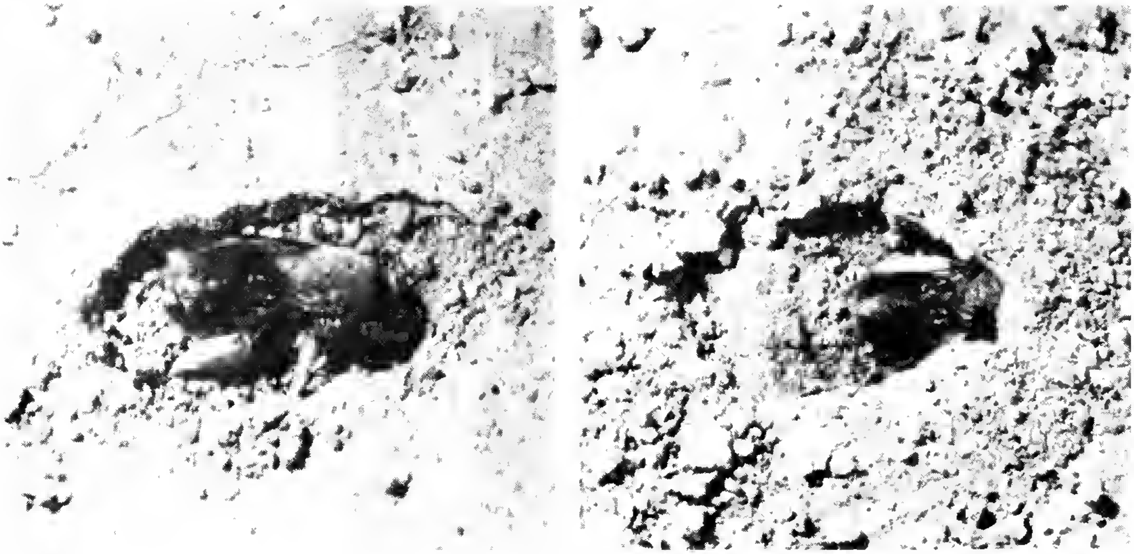


Figure 4 Pollen laden females of *Ctenocolletes ordensis* burrowing into loose soil in nest entrance pits.

early morning. Two clung to leaves and one to an *Acacia* flower using all legs. The antennae were held erect.

Nesting Biology of *Ctenocolletes ordensis*

This is the only species whose nests have been examined in detail.

A nesting population was discovered on Anketell Station between Mt Magnet and Sandstone on 3 September 1981 and was examined over the following two days. The area generally was one of dense mulga (*Acacia aneura*) shrubland but the nests occurred in disturbed ground adjacent to a road, on and near the path of a former (but now non-existent) railway. The reddish sandy loam soil was level and, near the road where it was relatively soft near the surface, bore medium dense regrowth. On the railway path it was compacted hard and its weathered surface was largely devoid of vegetation (Figure 3).

Females were observed entering and leaving burrows scattered irregularly in both hard and soft ground. At least 50 burrows occurred in an area 10 m x 30 m. They were not obviously aggregated but some were very close and six entrances were found within an area 40 cm wide. All were in bare ground.

Nest Architecture, Provisions and Immatures

Nests were characterized at the surface by roughly ovoid, sharp-edged pits (Figures 4, 5) varying in length from 15-30 mm. A shaft entrance was at one end of each pit. Tumuli were absent although a little loose soil was scattered about some pits and loose sand lay in the pit floors and blocked the burrow entrances.

Three separate excavations were made, one in the bare railway path and two in the softer vegetated zone. Altogether, seven active nests were exposed along with remains of several old, vacated nests. On the railway path the surface soil was so compacted to a depth of about 30 cm that it could only be chipped with a spade. Elsewhere the surface soil was more easily dug and below 30 cm the soil was everywhere much the same: moderately compacted, slightly moist, sandy loam containing patches of harder gravelly soil.

In each nest excavated the entry shaft extended laterally for 10-15 cm at an angle of only 10-20° to the horizontal and was partially filled with loose sand (Figure 5). Shafts then turned vertically and descended irregularly to depths of 30-60 cm where they turned more horizontally again and led to the cells. Shafts were circular in cross-section and 9 mm in diameter. Those through solid soil appeared to have unworked walls but some through soft soil were at least partially cemented.

Brood cells were encountered at depths of 45-77 cm. Some were open and being provisioned, some were closed and contained eggs on completed provisions, and the remainder were old vacated or failed cells from previous generations. Basically, cells were ovoid chambers at the ends of access burrows with built-in cemented earthen walls continuous with those of the burrows (Figure 6). The long axes of cells dipped to the rear and floors were flatter than ceilings.

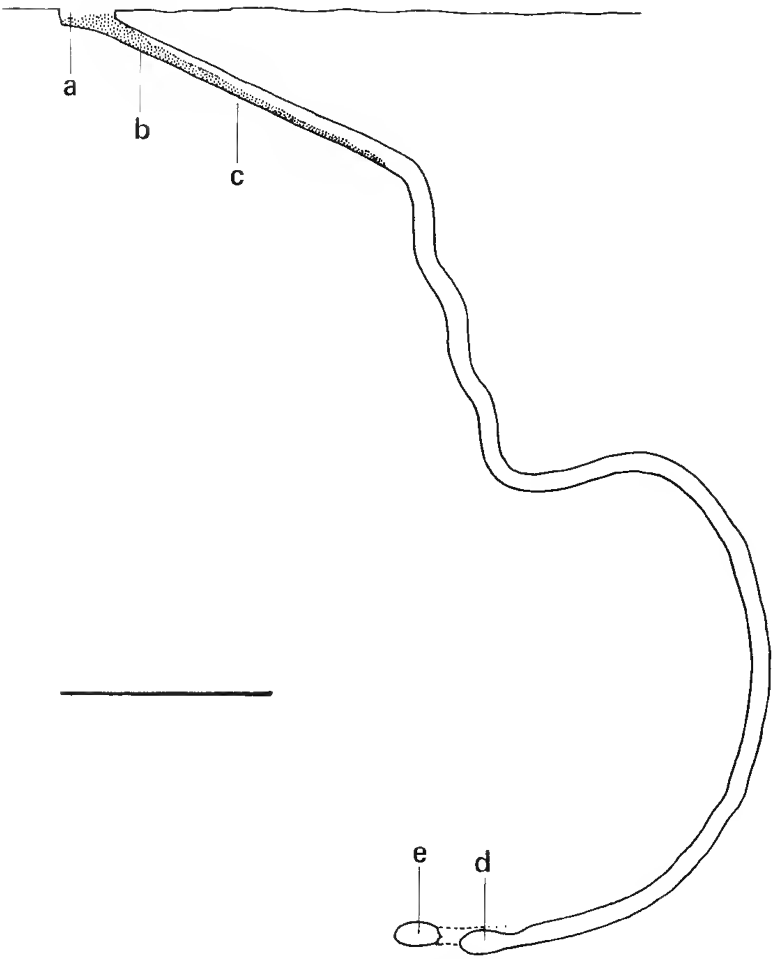


Figure 5 Nest of *Ctenocolletes ordensis* in profile: a, entrance pit; b, loose soil closing burrow; c, entrance shaft; d, open cell being provisioned; e, closed provisioned cell (access burrow soil-filled and connection with shaft obscure). Scale line, 10 cm.

During excavation, cells could be detected by their hardened gravelly outer coat which contrasted with the softer soil matrix and cells and their access burrows could be removed intact. The internal cell walls were composed of very fine gravel-free soil; it appears that the bees are able to separate finer and coarser grains as they build.

The inner surfaces of all cells were very smooth and shiny as if varnished. The gloss diminished slightly near the neck of each cell and was absent outside it. Drops of water placed on the inner walls of cells remained unabsorbed while others placed on the walls of access burrows or on the outer coats of cells were absorbed immediately. No lining could be peeled, scraped or flaked from the walls of untreated cells. However, when portion of a cell was soaked in water and detergent, a very delicate transparent membrane separated slightly from the earthen wall. It was flexible like a plastic film and could be peeled away. It was insoluble in xylene and turpentine, did not melt when heated and appeared amorphous under the microscope. Clearly, it was not a wax film but more probably a laminester (*sensu* Hefetz *et al.* 1979).

Completed provisioned cells were closed by elaborate earthen plugs (Figure 6). Initial closure was effected by a plug of fine compacted soil in the cell neck. Its inner surface was concave with a spiral pattern and was uncemented. Its exterior was also concave but smooth and cemented to a depth of about 3 mm. Following this plug was a short cavity filled with gravel and soil, then a thin cemented earth partition about 1 mm thick, concave and smooth externally and rough internally. The concave surfaces of both plug and partition were 11 mm in diameter and since all open access burrows were only 10 mm, females must enlarge the cell antechambers as they build in the closure. Although both concave surfaces were smoothed and looked like cell bases, they were rather flatter and were not waterproofed. Beyond the concave partitions the access burrows were filled with loose soil and gravel.

Five nests excavated had one open and one closed cell but no more than two cells were found in close proximity anywhere during the September 1981 dig (nor subsequently — see below). Where cells occurred in pairs they and their access burrows were side by side (or at least in parallel, not sequentially arranged).

Each of the open cells examined contained an amorphous mass of moist pollen lying in the rear (Figure 5). In consistency, it resembled completed pollen loads carried on the scopae of females (see under Flower Visiting and Foraging). Closed cells each contained a characteristically shaped pollen mass surmounted by an egg (Figures 6-8). The masses were khaki, smooth, uncoated, and 10.5-13.0 mm in length. They were uniformly moist throughout but firm enough that they could be handled gently without distorting. No free liquid was present in cells.

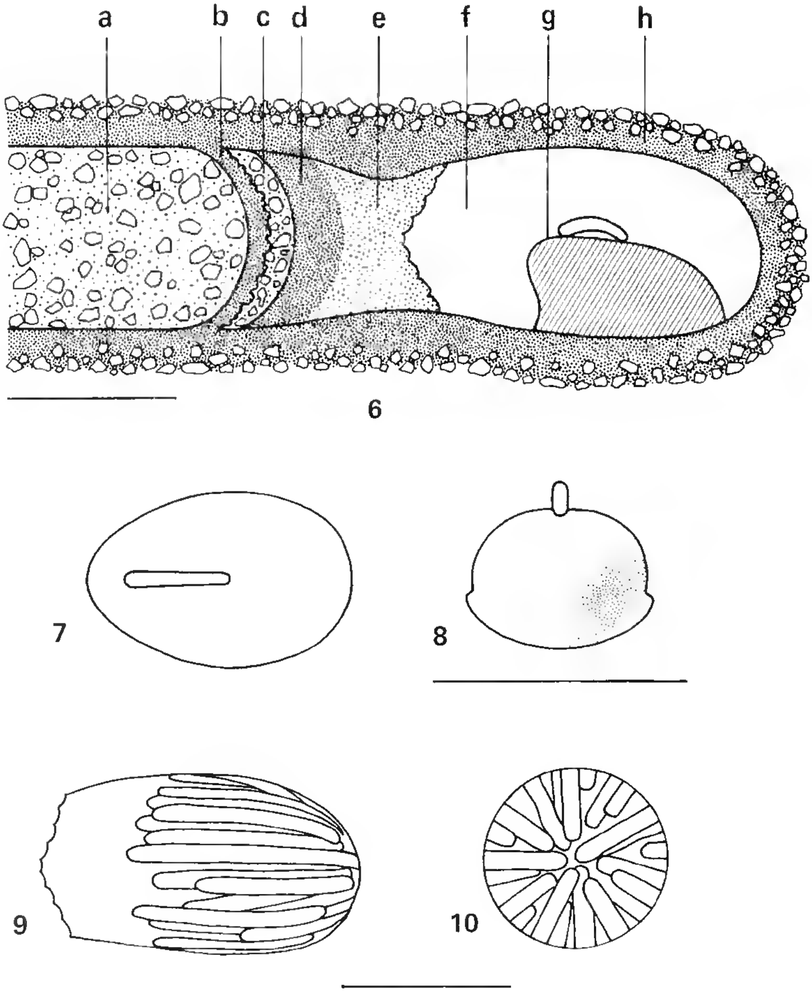
Some pollen masses returned to the laboratory in their cells gradually liquefied and slumped, filling the lower portions of the cells. After some weeks they congealed again.

On the first visit no immatures other than eggs were found. However, the site was revisited on 15-16 March 1982 and one of the excavations was reopened and extended. Several further cells were encountered (singly or in pairs as before) and five post-defaecating larvae obtained. There were no cocoons and the soft white larvae rested with their heads towards the cell plugs (whose spiral patterns were still evident). The walls of the inner 3/5 of each cell were streaked with flaky whitish faecal deposits (Figures 9,10).

Evidently, the bees may reuse old nest shafts: four shafts of active nests excavated in September connected with soil-filled burrows leading to old vacated cells.

Nest closure was not studied extensively but it was clear that shafts and access burrows are filled with soil after cell completion. In one such closed shaft examined closely on my March visit, two thin cemented earth partitions 4.5 cm apart were located in its upper reaches a few centimetres below the oblique entry shaft. They were virtually identical to the thin partitions forming part of cell closures.

In many respects, the nests of *C. ordensis* are like those described for *Stenotritus pubescens* (Houston 1975). Distinguishing features are the entrance pits, oblique sand-filled entry shafts, thicker built-in cell walls, smooth, cemented and concave outer surfaces of cell plugs, gravel-filled chambers outside cell plugs and



Figures 6-10 *Ctenocolletes ordensis*: 6, schematic sagittal section of newly completed brood cell and adjacent portion of access burrow (a, access burrow occluded by compacted gravelly soil; b, 'false cell-base' partition; c, antechamber filled with compacted gravelly soil; d, cemented outer portion of cell plug with smooth concave outer surface; e, compacted uncemented portion of cell plug with spiral-patterned inner surface; f, cell chamber; g, pollen mass surmounted by egg; h, cemented earth wall of cell with gravelly outer coat); 7, 8, pollen mass and egg in top and end views, respectively; 9, 10, larval faecal deposits on cell wall in side and end views, respectively. Scales lines, 1 cm.

the cemented earthen partitions (like cell bases) forming part of cell and shaft closures.

Comparison of the cell closure of *C. ordensis* (which appears to be unusually elaborate) with those of other bee families is hampered by lack of data for more than a few species: many authors in describing nest structure have failed to note details of more than the inner surface of the cell plug. The other surface is usually obscured by the soil barricade and, as in the case of *ordensis*, it requires very careful examination to reveal any surfaces or cavities. A smoothed concave and cemented outer surface of the cell plug has been reported for some Panurginae (Andrenidae) by Malyshev (1936) and Rozen (1968, 1971), a melittid (Rozen 1974) and is typical of ground-nesting Anthophoridae (Linsley, MacSwain and Smith 1956; Cardale 1968*a*, *b*; Linsley, MacSwain and Michener 1980; and many other authors). The inclusion of gravel-filled cavities and cemented earthen partitions in cell and shaft closures has no parallel amongst other short-tongued bees as far as I am aware but anthophorid bees such as *Amegilla* make multiple cell closures and plug shafts with concave cemented earthen partitions (personal observations).

The elaborate structure of cells would necessitate a high labour input and may explain the presence of only two cells per nest. However, it was not ascertained whether females construct more than one nest each.

The provisions of *C. ordensis* are also much like those of *S. pubescens*, differing slightly in the shape of the pollen mass and in the absence of free liquid under or around it. In both species larvae deposit faeces as linear streaks on the cell walls but *C. ordensis* deposits them over more of the cell than *S. pubescens*. Absence of cocoons is common to both species.

Adult Activity at Nests

With the exception of a single male grooming inself on shrubbery, all adults observed at the nest site in September were females (no adult activity was evident in March).

Females returning to the nest area usually hovered for a few seconds while orientating towards their nests. Then, when about 15 cm from them, they dropped swiftly into the pits and began burrowing into the loose-fill. Once a female had gained access to her burrow she would intermittently back up with simultaneous kicking movements of her hind legs and shove loads of sand into the entrance until it was completely blocked. The successive loads formed ripples in the loose-fill.

Imminent departure of a female from a nest was usually heralded by one or more shrill chirps (presumably produced by vibration of the thorax and folded wings). As a female emerged into the entry pit she performed the same kind of soil-shoving movements described above (but in reverse direction) to close the burrow entrance. Brief grooming was followed by swift departure.

A few females did not block their entrances and made swift entries and departures. They were unladen, unlike the majority of females which arrived heavily laden with pollen.

One female was observed apparently making final closure of her burrow at about 8 a.m. She was in her entrance pit facing away from the burrow and, after breaking down part of the pit wall in front of her (thus lengthening the pit) she backed up with the characteristic rearward kicking movements of the hind legs and pushed the loosened soil towards the burrow entrance. Alternately biting and shoving, she extended the pit to a length of 8 cm and filled most of it with loose sand. She then took flight and, after briefly inspecting the pit, departed.

There appeared to be only one female to a nest. Females were largely unperturbed by the presence of an observer and exhibited no aggression even when their nests were disturbed.

Female traffic at nests was observed from 8.18 a.m. to 5.20 p.m. (W.S.T.) in temperatures of 15-28°C.

Organisms Associated with Nests

During my September visit, two kinds of parasitoid wasps were observed in association with the bee nests: a *Hyptiogaster* species and a *Crassifoenus* species (Hymenoptera: Gasteruptiidae). One to a few specimens of each were seen searching the ground of the nest area in slow hovering flight at most times of the day. Adults of the first species were much smaller than those of the second (which approximated the bees in bulk, though not dimensions). A pair of *Hyptiogaster* hovered together for several minutes at the entrance of an occupied nest with their faces and antennae directed towards it but eventually departed without entering. Females of *Crassifoenus* were twice observed to enter burrows in the absence of bee occupants and spend several minutes within (presumably ovipositing). However, none of the cells excavated from any nest showed clear evidence of the wasps (nor any other insects). A hard black partition across the lumen of one old cell, though, may have been composed of the characteristic larval excrement of a gasteruptiid.

A large neuropterous larva of the family Ithoniidae was taken from a burrow at a depth of 77 cm, very close to old soil-filled cells and not far from newly constructed ones. However, it was not clear whether the larva was in a bee burrow or one of its own.

Nesting in Other Species

Only a few minor observations are available but tend to confirm the ground-nesting habits of the genus.

On 7 September 1981, about 30 km west of Sandstone, a female of *C. albomarginatus* was observed alighting at a simple burrow in a graded road drain. It proceeded to perform motions similar to those described above for *C. ordensis* females when entering and closing their burrow entrances. The soil was soft and sandy. No other burrows were evident and, as the female had not carried pollen and did not reappear, the burrow was not excavated.

Much time and effort has been expended searching for the nests of *C. smaragdinus* in areas where this species was both active and abundant but without success. Perhaps the bees nest solitarily or under cover. Some females were observed hovering close to the ground in an area of heath on white sand and especially near some very low prickly pincushion-like plants. One female began burrowing beneath the edge of such a tussock but abandoned its work after a few minutes.

Associated Organisms

Some insects associated with nests of *C. ordensis* were discussed above. Here I report on those organisms found associated with adults of *Ctenocolletes*. A survey of all adult specimens available revealed two kinds of phoretic organisms: triungulins (Coleoptera: Meloidae) and mites (Acarina: Acaridae).

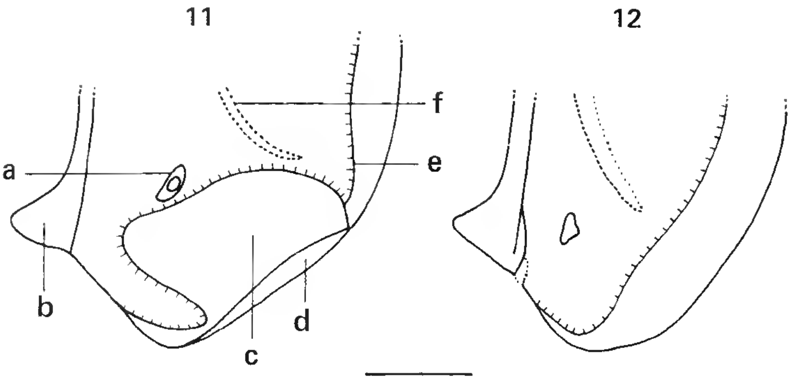
Solitary triungulins were found attached to hairs of the face, legs or propodeum of *C. nicholsoni* (1 ♂, 1 ♀), *C. rufescens* (1 ♀), and *C. smaragdinus* (1 ♀). This is a low incidence and carriage of triungulins is not proof that the bees' larvae are subject to meloid attack.

Three species of *Ctenocolletes* were found to carry hypopial mites: *albomarginatus, centralis* and *nicholsoni*. The incidence of mite infestation was quite high. With females, 17 of 20 *albomarginatus*, 25 of 28 *centralis* and 23 of 31 *nicholsoni* were carriers. The incidence on males was at least as high.

Specimens of hypopi were identified as Acaridae and represented (then) three undescribed species of an undescribed genus. The taxonomy and host relationships of the mites are dealt with in an accompanying paper (Fain 1984).

On female bees, mite hypopi were mainly found secreted in cavities (or pouches) beneath the lateral portions of the third and fourth metasomal terga. The cavities (which do not occur in mite-free species) are formed by invagination of the intersegmental membranes and convexity of the overlying cuticle (cf. Figures 11, 12). Up to 43 hypopi occupied each pouch and a total of 133 were carried by one female of *nicholsoni*. The hypopi are usually visible through the transparent integument. There are no conspicuous openings to the pouches and how the mites enter and leave them is not known but would seem to require some assistance from the bees. A few female bees also carried hypopi under the edges of other terga and scattered externally on the body. On males, hypopi occurred beneath the translucent lateral margins of the first to sixth metasomal terga and in the genital chamber.

Because no other function of the tergal pouches is apparent, their purpose may be to protect and transport mites. Hypopi are non-feeding, dispersal stage nymphs and do not harm adults carrying them. However, they may drop from adults in nests under construction, metamorphose into feeding nymphs and consume some material within brood cells. Some kinds of mites feed on bees' larval



Figures 11-12 Right lateral portions of fourth metasomal terga of *Ctenocolletes* females (inner views); 11, *C. nicholsoni* (a, spiracle; b, anterolateral apodeme; c, mite chamber; d, reflexed margin of tergum; e, line of attachment of intersegmental membrane; f, gradulus); 12, *C. ordensis.* Scale line, *c.* 1 mm.

food stores and immatures (Krombein 1962 and author's own unpublished observations of hylaeine and xylocopine bees). Such feeding activity is inimical to the bees' welfare and would not be favoured by natural selection of bee features. More likely, the mites associated with *Ctenocolletes* may feed in a beneficial manner, consuming larval faeces as occurs in nests of *Lithurge* (Houston 1971), thus reducing the chances of mould growth. Symbiotic relationships between mites and some vespoid wasps (which carry them in special pouches or acarinaria) have been reported by Krombein (1961).

Strepsiptera, commonly found as parasites of Colletidae and other bees, are not known from *Ctenocolletes.*

Conclusion

The information gathered so far provides only a very incomplete picture of the habits of *Ctenocolletes* and much more is required before one could confidently distinguish generic from specific traits. Comparisons of stenotritid habits with those of other families of short-tongued bees is hampered further by our incomplete knowledge of the latter. For example, nothing at all is recorded of the habits of several genera of Colletidae. However, combined with what is known of *Stenotritus,* the *Ctenocolletes* data permit some tentative generalizations concerning Stenotritidae. The family appears to consist of solitary burrowing bees whose nest architecture most resembles that of Andrenidae and Melittidae (also some Paracolletini, Colletidae, except for absence of cellophane-like material). Male mate-seeking behaviour involves both fast patrolling of food plants and prolonged hovering in stationary territories.

Features which may be derived for (or within) *Ctenocolletes* are the conjugate flights of males and foraging females, the thick built-in walls of cells and access burrows, incorporation of gravel in the latter and cell closures, and construction of 'false cell-base' partitions in cell and burrow closures.

Following my examination of *C. ordensis* nests I wonder now whether I did not overlook some details of cell arrangement and closure in nests of *Stenotritus pubescens* and further observations of *Stenotritus* nests are needed.

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Herpetofauna of the Lake MacLeod Region, Western Australia

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Abstract

The herpetofauna consists of 14 families, 46 genera and 104 species of frogs, turtles, lizards and snakes. Brief notes are given on their local distribution, relative abundance and habitat preferences. *Triodia*-dominated habitats are important in the north, where many reptiles are shared with the neighbouring Exmouth region. In the south *Acacia*-dominated habitats prevail; several elements of the Shark Bay region have their northern limits here. South-west Australian species are largely restricted to the coastal strip, which is notable for its winter showers and relatively cool summers.

Introduction

In their comparison of the herpetofauna of the Exmouth region with that of Shark Bay, Storr and Hanlon (1980) found considerable differences between the two areas, even though they were separated by a block of land only two degrees of latitude wide. That block of land is the subject of the present paper. It is located on the arid west coast of Western Australia between latitudes 23° and 25°S and extends inland to longitude 114°45′E (see Figure 1).

A generous grant from Mr and Mrs W.H. Butler to the Western Australian Museum enabled G. Harold and C.D. Winton to spend four weeks in October 1980 collecting in the Lake MacLeod region. Their specimens and observations and those of other visitors allow us to paint a broad picture of the herpetofauna. We are grateful to Mr A.J. Coventry for records and loans of specimens in the Museum of Victoria; the registered numbers of these specimens are prefixed with NMV. Specimens in the R series of the Western Australian Museum are cited without prefix.

This paper is one of several on the herpetofauna of the west coast of Western Australia. Others include Dell and Chapman (1977), Ford (1963), Smith (1976), Storr and Hanlon (1980), Storr, Hanlon and Dunlop (1983), Storr and Harold (1978, 1980*a*, 1980*b*) and Storr, Harold and Barron (1978).

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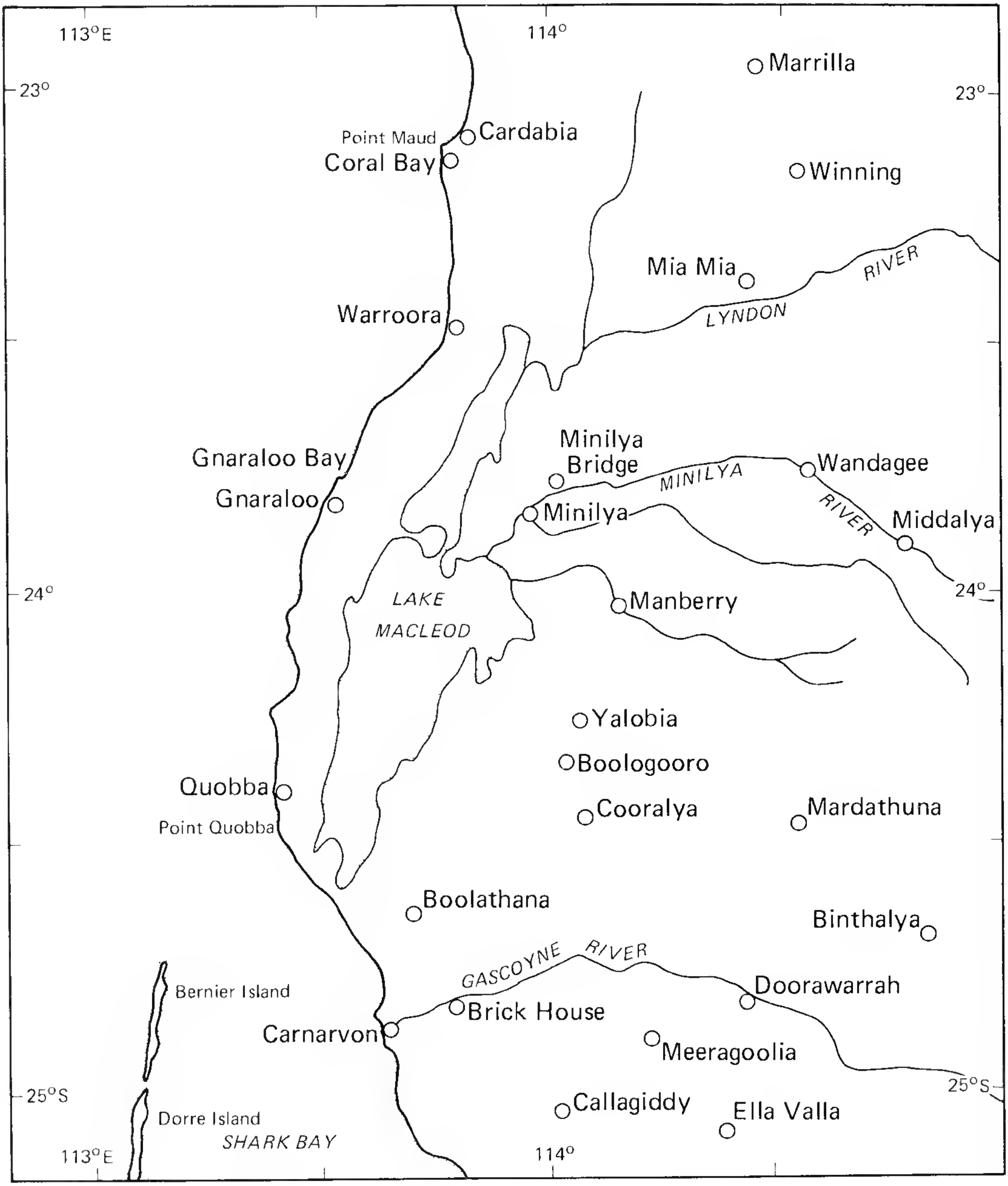

Figure 1 Map of Lake MacLeod region.

The Environment

Mean annual rainfall (21-25 cm) is fairly uniform throughout the region but its seasonality varies with distance from the sea: more in summer in the interior, more in winter on the coast (Table 1). Summers are much hotter in the interior than on the coast, e.g. mean daily maximum temperature in January is 40.2°C at Winning and 30.8°C at Carnarvon.

Table 1 Mean monthly and yearly rainfall (in mm) at Winning in the interior and Carnarvon on the coast.

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Winning	30	45	40	13	33	30	13	8	1	4	3	6	226
Carnarvon	20	23	15	9	42	50	46	17	4	4	1	1	232

Lying wholly within the Carnarvon Basin the region is one of gentle relief, and it is only in the far east, towards the low Gooch and Kennedy Ranges, that the altitude exceeds 150 m. The region is divisible into two zones: (1) the coastal strip; and (2) the remainder, herein termed the interior.

The Coast

The narrow strip of country 1-10 km wide along the coast consists largely of white sand dunes or white to pink sandplains overlying aeolian limestone, which is exposed here and there as sea cliffs or as small outcrops inland. On the white and less stable sands near the sea the low open vegetation is dominated by such typically south-western littoral plants as *Spinifex longifolius, Nitraria schoberi, Scaevola crassifolia* and *Acanthocarpus preissii.* Inland they soon give way to denser and more varied assemblages of plants, including scrubs of *Acacia coriacea* and other wattles, and hummock grasslands of *Triodia.*

Reptiles characteristic of the coastal strip include *Diplodactylus alboguttatus, D. ornatus, Tympanocryptis parviceps, Ctenotus fallens, Lerista lineopunctulata, Morethia lineoocellata* and *Vermicella littoralis.* Most of these are south-western species at or near the northern limit of their distribution. No frogs have yet been reported from this waterless tract, and none can be expected, except perhaps for *Arenophryne rotunda.*

The Interior

Here all soils are red regardless of texture (sands, loams or clays) or situation (floodplains, stony rises or desert sandridges). In the west, that is about Lake MacLeod (a large saltmarsh), the lower Gascoyne and the coastal plain south of Carnarvon, much of the land is low-lying and subject to inundation. Eastwards the country gradually rises towards the Precambrian Shield.

The various soil types, and consequently the plant associations, are so intermingled as to make it impossible to subdivide the interior into a few broad zones. Generally the vegetation is dominated by open *Acacia* scrubs in the south, and by open or sparsely wooded hummock grasslands (*Triodia*) in the north. The numerous intermittent watercourses are lined with river gums (*Eucalyptus camaldulensis*).

Reptiles characteristic of *Triodia*-dominated habitats include *Diplodactylus conspicillatus, Gehyra pilbara, Ctenophorus clayi, C. femoralis, Diporiphora winneckei, Ctenotus colleti rufescens, C. hanloni* and *C. iapetus.* All of them occur in the eastern deserts of Western Australia or are closely related to such taxa, and none of them extends south to the Shark Bay region.

Reptiles characteristic of *Acacia*-dominated habitats include *Diplodactylus squarrosus, D. strophurus, Caimanops amphiboluroides, Ctenophorus reticulatus, C. scutulatus, Ctenotus leonhardii, Egernia depressa, Lerista macropisthopus* and *L. muelleri.* All of these taxa are widespread in the mulga country of Western Australia, and most of them extend south to Shark Bay.

For further details of the physiography, soils and vegetation of the region see Beard (1975).

Annotated List

Leptodactylidae

Limnodynastes spenceri Parker, 1940

One record from the interior: two specimens of *Limnodynastes* (10359-60) collected at Minilya probably belong to this species rather than to *L. ornatus* (Gray).

Neobatrachus sutor Main, 1957

Common at claypans and river pools, north at least to the lower Lyndon (a specimen from Winning could have belonged to this species or to *N. centralis* [Parker, 1940]).

Neobatrachus wilsmorei (Parker, 1940)

Common about claypans and watercourses, north to Warroora and 25 km NE of Minilya Bridge.

Several specimens of *Neobatrachus* collected in February, August and October at Winning, Barrabiddy Creek, Boolathana and Carnarvon could not be identified beyond their not being *N. wilsmorei.*

Neobatrachus sp.

M. Mahony of Macquarie University believes that a specimen (76583) from 18 km E of Gnaraloo belongs to an undescribed species of *Neobatrachus.*

Uperoleia russelli (Loveridge, 1933)

Recorded from two localities in the interior: the Minilya River near Minilya Bridge (including a specimen feeding in a patch of damp grass on an evening in August) and the Gascoyne River at Rocky Pool (two heard calling in October).

Hylidae

Cyclorana maini Tyler and Martin, 1977

Moderately common about claypans and watercourses in the interior. Collected in summer and autumn (December-May) at Winning, Minilya, Barrabiddy Creek, 17 km N of Boologooro, Manberry, and 40 km NE and 10 km N of Carnarvon.

Cyclorana platycephala (Günther, 1873)

Two records from the interior: single specimens (33208-9) from south-west of Winning and at 16 km S of Minilya.

Litoria rubella (Gray, 1842)

Common about the Gascoyne and in the interior north to Mia Mia. As elsewhere, this frog has become a commensal of man, living in wells, water-taps, etc.

Cheloniidae

Chelonia mydas (Linnaeus, 1758)

There are three specimens (12927, 67328-9) from Carnarvon.

Dermochelyidae

Dermochelys coriacea (Linnaeus, 1766)

One record: a specimen (1942) from Carnarvon.

Cheluidae

Chelodina steindachneri Siebenrock, 1914

One record: a specimen (57317) from Carnarvon. It has also been collected just outside our northern boundary in 22°58′S, 114° 13′E.

Gekkonidae

Crenadactylus ocellatus horni (Lucas and Frost, 1895)

One record from far south-west: a specimen (NMV D1669) from Carnarvon.

Diplodactylus alboguttatus Werner, 1910

One record from west coast: eight specimens (71547-54) collected in low wattle and heath on whitish sand at Beagle Hill (Point Quobba). This represents a northward extension of known range of 150 km (from the Peron Peninsula).

Diplodactylus conspicillatus Lucas and Frost, 1897

The interior, south to 40 km NE of Carnarvon. Uncommon. Mainly red sands and sandy loams with *Triodia* and scattered *Acacia.*

Diplodactylus ornatus Gray, 1845

Coastal dunes from Point Maud south to Quobba. Uncommon.

Diplodactylus pulcher (Steindachner, 1870)

Throughout the interior. Moderately common. A wide variety of lightly vegetated red soils from stony clays to dune sands.

Diplodactylus rankini Storr, 1979

West coast, south nearly to Carnarvon (Miaboolia Beach). Common. Mainly in low vegetation of white dunes but also on samphire flats immediately inland from the dunes and on near-coastal pink sands.

Diplodactylus squarrosus Kluge, 1962

The interior, west nearly to Boolathana. Moderately common. Red soils (clays, loams and sands) with open *Acacia.*

Diplodactylus stenodactylus Boulenger, 1896

The interior, south to Cooralya and Mardathuna, and west nearly to Gnaraloo. Common. Red soils (sands to stony clays) with open *Acacia* and often with *Triodia.*

Diplodactylus strophurus (Duméril and Bibron, 1836)

Throughout the region. Moderately common. Open *Acacia* and other shrubs on a wide variety of soil types from the pinkish sands at Gnaraloo Bay to the red clays and sands of the interior.

Gehyra pilbara Mitchell, 1965

Northern interior south to Warroora and Mia Mia. Moderately common. On and in termitaria on red sands and sandy loams vegetated with *Triodia.*

Gehyra variegata (Duméril and Bibron, 1836)

Throughout the region. Very common. In trees and shrubs, especially of *Acacia*, on a wide variety of soil types.

Heteronotia binoei (Gray, 1845)

Throughout most of the region, but not yet recorded from far north-east around Winning. Common. Many habitat types, including white coastal sands.

Nephrurus levis occidentalis Storr, 1963

Throughout much of the region, but not recorded from north-east (north of the Lyndon). Common. Mostly red sands and sandy loams with low open *Acacia* and/or *Triodia*; also near-coastal white and pinkish sands.

Rhynchoedura ornata Günther, 1867

The interior, west to Minilya and Cooralya. Common. Red soils (sands, sandy loams and clay loams) with open *Acacia* and/or *Triodia.*

Pygopodidae

Aprasia rostrata fusca Storr, 1979

One record from north coast: a specimen (76888) collected in pink sand under leaf litter in *Acacia coriacea* shrubland near Gnaraloo.

Delma nasuta Kluge, 1974

One record: three specimens collected in *Triodia* on pale red sand 5 km SE of Gnaraloo.

Delma tincta DeVis, 1888

Throughout the region. Scarce.

Lialis burtonis Gray, 1835

Uncommon in white coastal dunes and near-coastal pink or red sands. Only one record from the interior: a specimen collected on red sandy loam with *Triodia* at an interdune 26 km NE of Minilya Roadhouse.

Pygopus nigriceps nigriceps (Fischer, 1882)

The interior, west nearly to Carnarvon (Brown Range). Uncommon. Red sands and sandy loams with open *Acacia.*

Agamidae

Caimanops amphiboluroides (Lucas and Frost, 1902)

Regionally known from only one small area in north-western interior: *Acacia* scrub at 6 km SE, 13 km SE and 34 km S of Warroora.

Ctenophorus clayi (Storr, 1966)

Much of the interior, but not far south (south of 24°40′S). Moderately common. Red sandridges with *Triodia* and red sandplains with open *Acacia,* low shrubs and *Triodia.*

Ctenophorus femoralis (Storr, 1965)

The interior, south to Warroora, Yalobia and Mardathuna. Common. Red sandridges with low open vegetation, especially *Triodia, Acacia* and other shrubs.

Ctenophorus inermis (DeVis, 1888)

Throughout the region. Very common. Most habitats, but not white coastal dunes.

Ctenophorus isolepis isolepis (Fischer, 1881)

One record from far north-western interior: eight specimens from 10 km N of Warroora.

Ctenophorus maculatus badius (Storr, 1965)

Far west, south to Carnarvon and east to the Minilya-Exmouth road (36 km N of Warroora). Common. Coastal and near-coastal red, pink or white sandridges and sandplains with low open shrubs, tussock grasses, sedges or *Triodia.*

Also a slightly different population on red sandridges with open *Acacia* around Doorawarrah in the southern interior. These lizards are larger and have a brighter red back than those from the coast.

Ctenophorus reticulatus (Gray, 1845)

Much of the region, but not the north-east (north of Minilya). Common. Mainly open *Acacia* on a wide variety of red soils.

Ctenophorus rubens (Storr, 1965)

Eastern interior, south to Yalobia and Mardathuna; also small area in western interior between Gnaraloo and Lake MacLeod. Common. *Triodia* (and occasionally tussock grasses) on red sands, sandy loams and interdunal clays.

Ctenophorus scutulatus (Stirling and Zietz, 1893)

Throughout the interior, west to Warroora, Boolathana and Brick House. Moderately common. Mainly open *Acacia* on red sands and loams.

Diporiphora winneckei Lucas and Frost, 1896

North-eastern interior, south to Wandagee (and west to Marrilla). Scarce. Red sands and loams with *Triodia.*

Gemmatophora gilberti gilberti (Gray, 1842)

Far north-west coast, south to Coral Bay. Moderately common. Beaches, cliffs and dunes; sheltering in tidal debris, *Spinifex longifolius* and shrubs.

Gemmatophora longirostris (Boulenger, 1883)

Patchily distributed throughout the region, but not reported from coastal country between Quobba and Carnarvon. Common in river gums and other vegetation along watercourses and around claypans; moderately common in *Acacia* scrubs and *Ficus platypoda* thickets of north-western interior south to Gnaraloo; uncommon elsewhere.

Moloch horridus Gray, 1841

The interior. Uncommon. Red sands and sandy loams with low open vegetation.

Pogona minor minor (Sternfeld, 1919)

Throughout the region. Common. Most habitats, including white coastal sands.

Tympanocryptis cephala Günther, 1867

One record from far eastern interior: a specimen (14060) collected at Wandagee.

Tympanocryptis parviceps Storr, 1964

Coastal dunes south to Point Quobba. Moderately common. White sands with low open vegetation.

Scincidae

Cryptoblepharus carnabyi Storr, 1976

Regionally known only from mallee scrub 5 and 9 km SE of Gnaraloo and from a park in Carnarvon.

Cryptoblepharus plagiocephalus (Cocteau, 1836)

One record from extreme north-west: a specimen (16967) collected on a limestone outcrop 13 km N of Cardabia.

Ctenotus colletti rufescens Storr, 1979

Two records from eastern interior: solitary individuals observed by G. Harold on red sands vegetated with low shrubs and *Triodia*, one at 6 km N of Mia Mia, the other at 3 km NW of Mardathuna.

Ctenotus fallens Storr, 1974

One record from west coast: a specimen (32588) collected in dense scrub at Point Quobba. (Three specimens from Ningaloo, a little north of the present region, were included by Storr and Hanlon [1980] in *C. saxatilis* but are better treated as *C. fallens*.)

Ctenotus hanloni Storr, 1980

The interior, west nearly to Gnaraloo and south to Mardathuna. Uncommon. Red sandy loams and pink sands with *Triodia*.

Ctenotus helenae Storr, 1969

Two records from far northern interior: one specimen (36080) collected in *Triodia-Acacia* on clay near Winning, the other (63682) among grass tussocks on red clay with low open *Acacia* 32 km E of Cardabia. (The specimen [5340] cited by Storr [1975] as coming from 'near Carnarvon' was actually collected at Marrilla.)

Ctenotus iapetus Storr, 1975

Northern interior, south to Quobba Station and Mia Mia. Uncommon. Red sandridges and sandplains with *Triodia.*

Ctenotus leonhardii (Sternfeld, 1919)

The flatlands east of Lake MacLeod, from 26 km E of Minilya Bridge south to 40 km NE of Carnarvon. Uncommon. Clayey floodplains and adjacent sandplains.

Ctenotus pantherinus ocellifer (Boulenger, 1896)

Northern interior, south and west nearly to Gnaraloo. Uncommon. Red sands and brownish loams with low open vegetation.

Ctenotus schomburgkii (Peters, 1863)

One record from far northern interior: a specimen (63683) collected among grass tussocks and low open *Acacia* on red clay 32 km E of Cardabia.

Ctenotus severus Storr, 1969

One record: a specimen (8214) from Warroora.

Ctenotus uber uber Storr, 1969

North-eastern interior, west to Winning and south to Wandagee. Uncommon. Red loamy flats.

Egernia depressa (Günther, 1875)

Western interior, north to Warroora and east to Boologooro. Moderately common. Mainly *Acacia* scrubs, where it commonly shelters in hollow logs.

Eremiascincus fasciolatus (Gunther, 1867)

One record from far eastern interior: a specimen (71739) collected on a red sandridge 16 km SE of Mardathuna.

Eremiascincus richardsonii (Gray, 1845)

One record: three specimens (8212-3, 8232) from Warroora.

Lerista bipes (Fischer, 1882)

North-eastern interior, south and west to Mia Mia. Uncommon. Sparsely vegetated, red sands and sandy loams.

Lerista connivens Storr, 1972

Western, east to 12 km NW of Mia Mia and 27 km E of Cooralya. Uncommon. In litter beneath *Acacia* on red or brown sands and sandy loams.

Lerista elegans (Gray, 1845)

Southern interior, north to Gnaraloo and Mardathuna. Scarce. In or under leaf litter on red or pink sands.

Lerista haroldi Storr, 1983

The unique specimen (81199) of this skink came from 0.5 km S of Gnaraloo HS.

Lerista lineopunctulata (Duméril and Bibron, 1839)

West coast, south to Point Quobba and inland to 14 km SE of Gnaraloo. Moderately common. Mainly in white beach dunes, but also further inland on pinkish sands and pale brown sandy loams with low shrubs and *Triodia* or *Atriplex*. (The specimens [4775-6] cited by Storr [1972] as coming from Carnarvon were actually collected in the Exmouth region.)

Lerista macropisthopus (Werner, 1903)

The interior, north to Gnaraloo and Mia Mia; also coast at 2 km SSW of Carnarvon. Common. Mainly in leaf litter under *Acacia* and *Eucalyptus* (mallee) on red loams and sands; also in litter beneath shrubs on coastal white sands near Carnarvon.

Lerista muelleri (Fischer, 1881)

The interior, west to 21 km NE of Warroora, Boologooro and Brick House. Common. Under leaf litter beneath *Acacia* and *Eucalyptus* (mallee) on red sands, loams and clays.

Lerista nichollsi petersoni Storr, 1976

Two records from eastern interior: two specimens (81828-9) from 10 km N of Winning, and one (76842) collected in soil under litter in open *Acacia-Triodia* on red sandy loam 10 km W of Manberry.

Lerista planiventralis (Lucas and Frost, 1902)

Uncommon in west, on pinkish sands inland to Warroora and Gnaraloo. Also one record from south-eastern interior: a specimen (71597) collected on a red sandridge with open *Acacia* and other shrubs 9 km SE of Doorawarrah.

Lerista praepedita (Boulenger, 1877)

Regionally recorded only at or near Gnaraloo. Common. In soil under litter on pink or red sands vegetated with *Acacia, Eucalyptus* and other shrubs.

Lerista uniduo Storr, 1984

The interior, west nearly to Gnaraloo (10 km SSE of homestead) and Carnarvon (16 km E of town). Common. Red or pale brown sands and sandy loams with open *Acacia* or other low trees over *Triodia, Plectrachne* or soft grasses.

Menetia greyii Gray, 1845

Widely but sparsely distributed throughout region, including islet off Point Quobba. Locally common (Gnaraloo) but generally scarce. Leaf litter, especially beneath *Acacia* scrubs on sandy soils.

Morethia lineoocellata (Duméril and Bibron, 1839)

West coast, inland to 5 km SE of Gnaraloo. Uncommon. White coastal dunes and near-coastal white or pinkish sands with low open vegetation.

Morethia obscura Storr, 1973

One record: two specimens (76717-8) collected in leaf litter beneath mallee over low open *Acacia* and *Triodia* on a red sandridge 9 km SE of Gnaraloo.

Morethia ruficauda exquisita Storr, 1973

One record from far northern interior: a specimen (63690) from 13 km S of Marrilla.

Omolepida branchialis (Günther, 1867)

Northern interior, south to Gnaraloo, Manberry and Mardathuna. Uncommon. In *Triodia* or leaf litter on red or pinkish sands.

Tiliqua multifasciata (Sternfeld, 1919)

One record from interior: a specimen (22946) from 20 km N of Boologooro.

Tiliqua occipitalis (Peters, 1863)

Far south-west, north to 23 km NNW of Carnarvon and east to Brick House. Scarce.

Tiliqua rugosa rugosa (Gray, 1827)

Far south-west, north to Boolathana and east to Brick House. Common in the Carnarvon plantations; uncommon elsehwere.

Varanidae

Varanus acanthurus Boulenger, 1885

One record from far north: a specimen (76584) collected in a termitarium 11 km NE of Warroora.

Varanus caudolineatus Boulenger, 1885

The interior, west to Warroora (and Callagiddy). Scarce.

Varanus eremius Lucas and Frost, 1895

The interior, west to Boologooro (and Callagiddy). Scarce. Red sands. One observed pursuing an adult *Ctenophorus rubens.*

Varanus giganteus (Gray, 1845)

One record from far north-west: one observed at a limestone gully 26 km N of Warroora.

Varanus gouldii (Gray, 1838)

The interior, west nearly to Carnarvon (11 km E of town). Uncommon. Red sands, loams and clays, usually with open *Acacia.*

Typhlopidae

Ramphotyphlops grypus (Waite, 1918)

One record from the interior: a specimen (NMV D4812) from Middalya. (It has also been collected at Callagiddy, just south of our region.)

Ramphotyphlops hamatus Storr, 1981

One record from the interior: a specimen (34570) from Rocky Pool, Gascoyne River (50 km E of Carnarvon).

Boidae

Liasis childreni (Gray, 1842)

Evidently widespread and moderately common; the seven regional specimens in the Western Australian Museum come from Warroora, Wandagee, Boologooro and Carnarvon, and it has been collected at Callagiddy just south of our region.

Liasis perthensis Stull, 1932

One record from the interior: a specimen (NMV D4568) from Middalya.

Elapidae

Acanthophis pyrrhus Boulenger, 1898

Three records from north-eastern interior: a specimen (49985) collected between Manberry and Williambury Stations, and two (71228, 71601) from red sandy soils with *Acacia* and *Triodia* at 16 km NNW of Mia Mia and 5 km SW of the Lyndon River bridge respectively.

Demansia calodera Storr, 1978

Moderately common near west coast, but only one record from more than 20 km inland, namely a specimen (14055) from Wandagee Station.

Demansia reticulata cupreiceps Storr, 1978

Eastern interior, generally west to Boologooro (and Callagiddy); also the lower Gascoyne downstream nearly to Carnarvon. Common. As in the Exmouth region, the ranges of the two *Demansia* tend to be mutually exclusive.

Denisonia fasciata Rosén, 1905

Eastern interior, west to Minilya (and Ella Valla). Uncommon.

Furina ornata (Gray, 1842)

One record from northern interior: a specimen (80702) collected on red loam vegetated with *Acacia* 27 km SW of Mia Mia.

Pseudechis australis (Gray, 1842)

Western, east to the Minilya-Exmouth road (50 km N of Warrora) and Meeragoolia. Apparently uncommon.

Pseudonaja modesta (Günther, 1872)

The interior, west to Warroora and Boolathana. Common; apparently outnumbering its congener (*P. nuchalis*) in the north-east and far east. In a wide variety of open or lightly wooded habitats and on all soil types from red sands to reddish clays.

Pseudonaja nuchalis Günther, 1858

Throughout the region. Common. Even wider in its habitat preferences than *P. modesta* and outnumbering that species in the western half of the region.

Rhinoplocephalus punctatus (Boulenger, 1896)

Two records from north-eastern interior: a specimen (80725) from Winning and one (NMV D5381) from Minilya.

Vermicella approximans (Glauert, 1954)

One record: a specimen (81710) caught after dark when it surfaced on red sand in interdune 10 km SSE of Gnaraloo.

Vermicella bertholdi (Jan, 1859)

The interior, west nearly to Carnarvon, e.g. 8 km SSE of Boolathana. Moderately common.

Vermicella littoralis Storr, 1968

West coast, south to Gnaraloo. Moderately common. White coastal dunes and the pinkish sands a little further inland.

Hydrophiidae

Ephalophis greyii M.A. Smith, 1931

One record: a specimen (32023) from Carnarvon.

Hydrophis elegans (Gray, 1842)

Several records: a specimen from the ocean beach near Warroora, one from the beach at Point Quobba, and nine from Carnarvon (offshore as well as on beaches).

Hydrophis major (Shaw, 1802)

There are 13 specimens in the Western Australian Museum from Carnarvon and vicinity, including the seas 70 km NW and 40 km SW of the town and Miaboolia Beach.

Pelamis platura (Linnaeus, 1766)

Two records: a specimen (9409) from Quobba, and one observed by P. Griffin on the surface of the sea off Point Quobba in November 1977.

Discussion

The herpetofauna of the region comprises 46 genera and 104 species distributed among 14 families as follows:

Leptodactylidae	3 genera	5 species
Hylidae	2 genera	3 species
Cheloniidae	1 genus	1 species
Dermochelyidae	1 genus	1 species
Cheluidae	1 genus	1 species
Gekkonidae	6 genera	14 species
Pygopodidae	4 genera	5 species
Agamidae	6 genera	16 species
Scincidae	9 genera	33 species
Varanidae	1 genus	5 species
Typhlopidae	1 genus	2 species
Boidae	1 genus	2 species
Elapidae	7 genera	12 species
Hydrophiidae	3 genera	4 species

Although the region covers a much greater area (*c.* 26 000 sq. km) than the neighbouring Exmouth and Shark Bay regions, it has received far less attention from herpetologists. This and the high number of species known from only one or two records indicate that several more remain to be collected. Among these species is *Menetia surda,* which has been recorded in both the Exmouth and Shark Bay regions. Some of the species known from only a few kilometres outside our region can also be expected to occur here, e.g. *Ctenotus calurus, C. piankai* and *Varanus brevicauda* which have been collected at Marrilla to our immediate north; *Egernia inornata* which has been collected at Merlinleigh just east of our region; and *Ctenotus mimetes, Egernia stokesii badia* and *Rhinoplocephalus monachus* which have been collected to our immediate south.

The region has only 4 genera and 5 species of pygopodid lizards, compared with 4 genera and 6 species in the Exmouth region and 6 genera and 11 species at Shark Bay. This impoverishment is almost certainly due to the relative homogeneity of the Lake MacLeod region. The Exmouth region includes extensive areas of rocky country, a habitat type almost completely lacking in the present region; and climatic diversity in the Shark Bay region (which permits the juxtaposition of distinct faunas) contrasts with the climatic uniformity of the Lake MacLeod region.

With regard to agamid lizards, however, the present region is the richest on the west coast. It has 6 genera and 16 species, compared with 4 and 14 at Exmouth and 3 and 8 at Shark Bay. It so happens that the Australian Agamidae are most diversified in arid and seasonally arid climates. Now the present region is not only the most arid on the west coast, it also lies partly within both of the major divisions of the Australian arid zone, namely the northern with its *Triodia*-dominated habitats, and the southern with its *Acacia*-dominated habitats. Nine of the 16 species of Agamidae recorded from the Lake MacLeod region are confined or almost confined to one or other of these divisions of the arid zone: *Ctenophorus clayi, C. femoralis, C. i. isolepis, C. rubens, Diporiphora winneckei* and *Moloch horridus* favouring the *Triodia*-dominated habitats; and *Caimanops amphiboluroides, Ctenophorus reticulatus* and *C. scutulatus* favouring the *Acacia*-dominated habitats.

In their comparison of the Exmouth and Shark Bay regions, Storr and Hanlon (1980: 438) pointed out that in most families only half of the species extended from one region to the other. This implied that many of the amphibians and reptiles in the intervening Lake MacLeod region were at either the northern or southern limit of their distribution.

On the west coast and coastal plains of Western Australia eight taxa attain their northern limit in the Lake MacLeod region. Three of these, *Diplodactylus alboguttatus, Morethia obscura* and *Tiliqua r. rugosa*, are western or southern species that extend northwards in an ever-narrowing strip along the coast. The others, *Neobatrachus sutor, N. wilsmorei, Ctenotus severus, Lerista connivens* and *Tiliqua occipitalis*, are more or less widely distributed in the western half of the arid and semi-arid zones of southern Western Australia.

A much larger number of taxa (23) reach their southern limit in the Lake MacLeod region. One of these, *Gemmatophora g. gilberti*, is a northern lizard that extends down the west coast to the far north of the present region. Another two, *Diplodactylus rankini* and *Aprasia rostrata fusca*, are endemic to the upper west coast of Western Australia. Another six, *Ctenotus helenae, C. u. uber, Lerista* *bipes, Varanus acanthurus, Acanthophis pyrrhus* and *Furina ornata,* are widespread in the arid zone of Western Australia. A fourth category consists of species whose distribution is centred on the Pilbara, namely *Cyclorana maini, Gehyra pilbara* and *Liasis perthensis.* The largest category is that of taxa which are widespread in the arid zone of northern Australia: *Diplodactylus conspicillatus, Ctenophorus clayi, C. i. isolepis, Diporiphora winneckei, Ctenotus hanloni, C. pantherinus ocellifer, Eremiascincus fasciolatus* and *Rhinoplocephalus punctatus* or are derivatives of such taxa, viz. *Ctenotus colletti rufescens* (from *C. c. nasutus*) and *C. iapetus* (from *C. quattuordecimlineatus*). Many of these taxa and *Ctenophorus femoralis* (a species confined to the Onslow, Exmouth and Lake MacLeod regions) are inhabitants of red sandridges and sandplains dominated by *Triodia.*

Finally there are the eight species known from the Lake MacLeod region but not the Exmouth or Shark Bay regions, namely the frogs *Cyclorana platycephala, Limnodynastes spenceri* and *Uperoleia russelli,* the agamid lizards *Caimanops amphiboluroides* and *Tympanocryptis cephala,* the skinks *Ctenotus leonhardii* and *Lerista haroldi,* and the blind snake *Ramphotyphlops hamatus.* Apart from the endemic *Lerista haroldi,* all these species are characteristic of heavy soils, a habitat type that is well developed in this region about the floodplains of the Lyndon, Minilya and Gascoyne Rivers.

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A New *Ctenotus* (Lacertilia: Scincidae) from Western Australia

G.M. Storr*

Abstract

The new species, *C. zastictus,* is a member of the *C. atlas* species-group. It is confined to a sandplain near the mid-west coast of Western Australia.

Introduction

In November 1982 L.A. Smith and R.E. Johnstone visited a sandplain south of Shark Bay, where they collected two specimens of an undescribed *Ctenotus.* Subsequently three more specimens were collected within a kilometre of the first two.

Ctenotus zastictus sp. nov.

Figure 1

Holotype

R84300 in Western Australian Museum, collected on 7 August 1983 by G. Harold and C. Winton at 16 km S of Hamelin HS, Western Australia, in 26°34'S, 114°14'E.

Paratypes

North-West Division (W.A.)

17 km S Hamelin HS (81783-4), and 16 km S (82732-3).

Diagnosis

A long-tailed member of the *Ctenotus atlas* species-group (Storr *et al.* 1981) with 8 white stripes (paravertebral, dorsolateral, midlateral and ventrolateral) and 4 series of pale brown spots (laterodorsal and upper lateral). Some members of the *atlas* group have an upper lateral series of spots, but the present species alone has a laterodorsal series.

Description

Snout-vent length (mm): 55-60. Length of appendages (% SVL): foreleg 26-29, hindleg 48-50, tail 248-258 (N 3).

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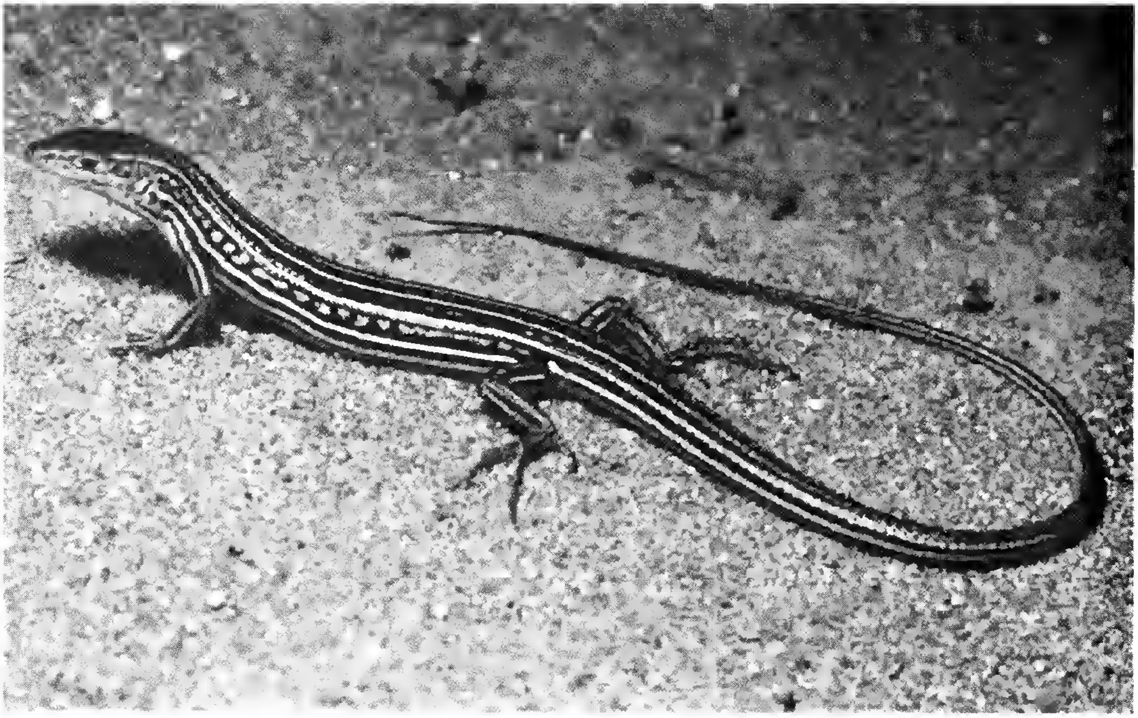

Figure 1 Holotype of *Ctenotus zastictus*, photographed in life by G. Harold.

Nasals in short to moderate contact. Prefrontals in moderate contact (N 4) or narrowly separated (1). Supraoculars 4, first three in contact with frontal, second wider than third but not wider than first. Supraciliaries 7, fourth to penultimate considerably smaller than others. Upper ciliaries 10-11. Second loreal 1.8-2.3 times as wide as high. Presuboculars 2. Upper labials 8. Ear lobules 3-4, mostly subacute, second usually largest. Nuchals 3-4. Midbody scale rows 24 (N 1) or 26 (4). Toes compressed; 24-25 lamellae under fourth, each with a narrow to moderately wide callus.

Head dark brown. Back and sides blackish with 8 white stripes (a very narrow paravertebral and dorsolateral, narrow midlateral and a moderately narrow ventrolateral) and 4 series of pale brown or brownish-white spots or short dashes (a variably developed laterodorsal beginning well behind arm and terminating at base of tail, and an upper lateral from ear to base of tail). Tail brown with 6 pale brown or brownish-white stripes (paravertebral, dorsolateral and midlateral) continuous with those on body. Legs dark brown, striped with pale brown. Lower surfaces whitish, tinged in life with green.

Distribution

Confined to an isolated belt of *Triodia* and *Eucalyptus* on red sand south of Shark Bay, Western Australia.

Remarks

The above *Triodia/Eucalyptus* covers about 150 sq. km on Hamelin and Coburn Stations. It is also notable for the only known population of *Ctenophorus rubens* south of Lake MacLeod (Storr and Harold 1980).

Ctenotus zastictus is probably nearest to *C. iapetus* Storr of the Exmouth region and could have differentiated from that species by the modification of the laterodorsal and upper lateral stripes into series of spots.

The name is derived from the Greek *za-* (much) + *stictos* (spotted).

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SHORT COMMUNICATIONS

Rec. West. Aust. Mus. 1984, **11** (2): 197-199

First Record of Painted Aboriginal Rock Art in a South-Western Australian Limestone Cave

Kate Morse*

In November 1982 Mr M. Herne and other local amateur speleologists reported the discovery of two Aboriginal painted hand stencils at Old Kudardup cave some 6 km north-west of Augusta in the Cape Leeuwin-Cape Naturaliste region. (Western Australian Museum Aboriginal Sites Registration Number S1942; National Map 1:100 000 grid reference, Series R611, Sheet 1929 243 058). A Western Australian Museum party recorded and photographed the stencils in March 1983.

Old Kudardup is one of many limestone caves developed in the aeolian calcarenite which caps the Precambrian crystalline rocks of the Leeuwin-Naturaliste block (Lowry 1967). The cave is situated on a limestone ridge densely vegetated with acacia and casuarina thickets, patches of blackboy and low peppermint woodland. Westwards, coastal heath with intermittent patches of open peppermint woodland and closed scrub extends some 4 km to the sea (Beard 1981). The region is well-watered and the forest-heath environment would have provided numerous resources for Aboriginal hunter-gatherers (cf. Dortch 1979: 275).

The two stencils are located on the north wall of the cave, near the entrance, and at the top of a talus slope leading down to a large vaulted chamber some 200 m in diameter. The stencils are approximately 70 cm apart and situated about 2 m above the present surface of the slope. The wall of the stencils is undercut and extensively weathered, and neither of the stencils is very distinct. Both are of a human left hand, possibly of the same individual, and each is made in reddish-brown ochreous paint (Figure 1).

Several artefacts of Eocene fossiliferous chert collected from the floor of the main chamber provide the only other evidence for Aboriginal use of the cave. The presence of the chert suggests that the cave was known and visited by Aborigines some time prior to the Middle Holocene. At this time, sources of the stone, thought to be located on the continental shelf, would have been submerged by post-glacial sea level rise (Glover 1975; 1979; see also Ferguson 1980; Pearce 1977). A partially collapsed pit, dug by persons unknown, and located in the large lower chamber, extends to a depth of some 2 m and reveals a banded sandy deposit but no archaeological material. No other pits have been dug.

Old Kudardup adds to the half dozen caves in the Leeuwin-Naturaliste region known to contain archaeological material, the most noted being the late Pleistocene deposit at Devil's Lair (Dortch 1979 and refs.). It is unknown whether

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the stencils described here are contemporaneous with the fossiliferous chert artefacts. If they are, their probable Late Pleistocene to Middle Holocene age lends support to Maynard's proposal that stencils are used from an early phase in the development of Australian art (Maynard 1976).

The Old Kudardup hand stencils are the first known examples of painted rock art in a south-western Australian limestone cave, and are an important find as they occur in an area previously noted for its conspicuous lack of Aboriginal art sites (Crawford 1972; Davidson 1952; Hallam 1981; Merrilees *et al.* 1973; Serventy 1952). Nearly all of the very few known south-western art sites have been described or mentioned in publication. These include paintings in two granite rock shelters near York (Hallam 1975: 85, 94; Serventy 1952); enigmatic engraved markings in limestone in Orchestra Shell Cave north of Perth (Hallam 1974), and at Morfitt's Cave south of Mandurah (Dortch 1976: 41); at least two engraved or scratched limestone plaques from Devil's Lair (Dortch 1976), and the recently published animal track engravings on the Scott River near Augusta (Clarke 1983).

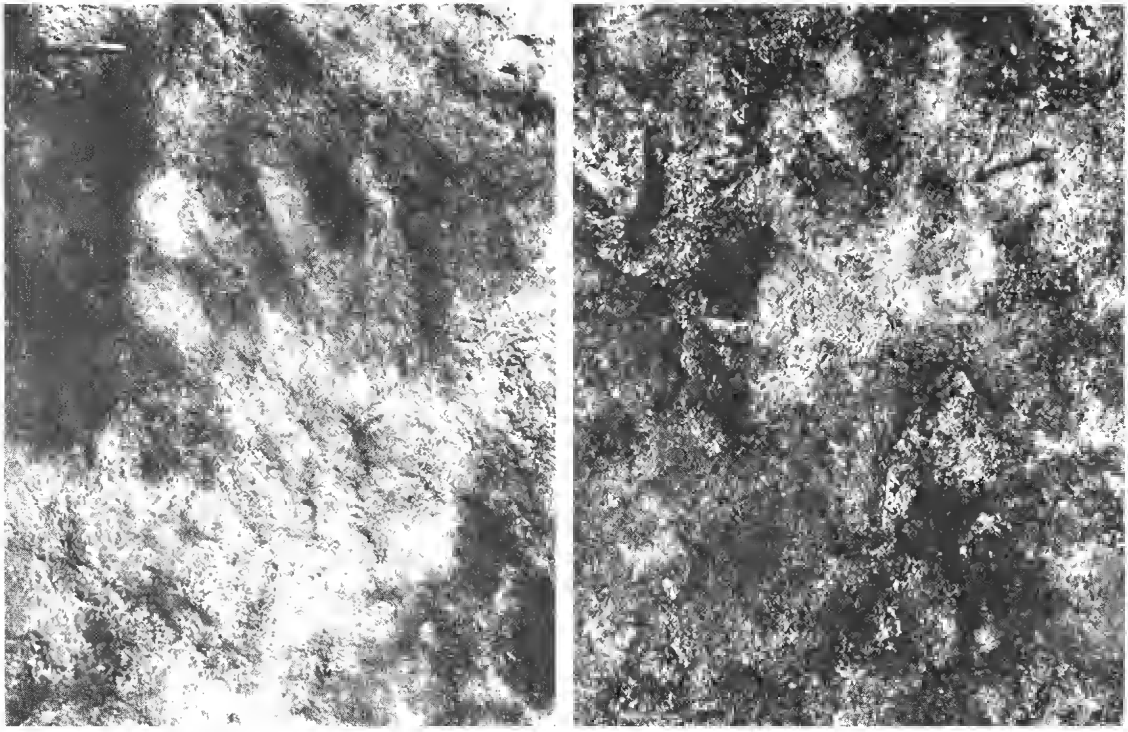

Figure 1 Two Aboriginal painted hand stencils, Old Kudardup Cave, south-western Australia. The matchstick is 4 cm long. Photographed by Douglas Elford.

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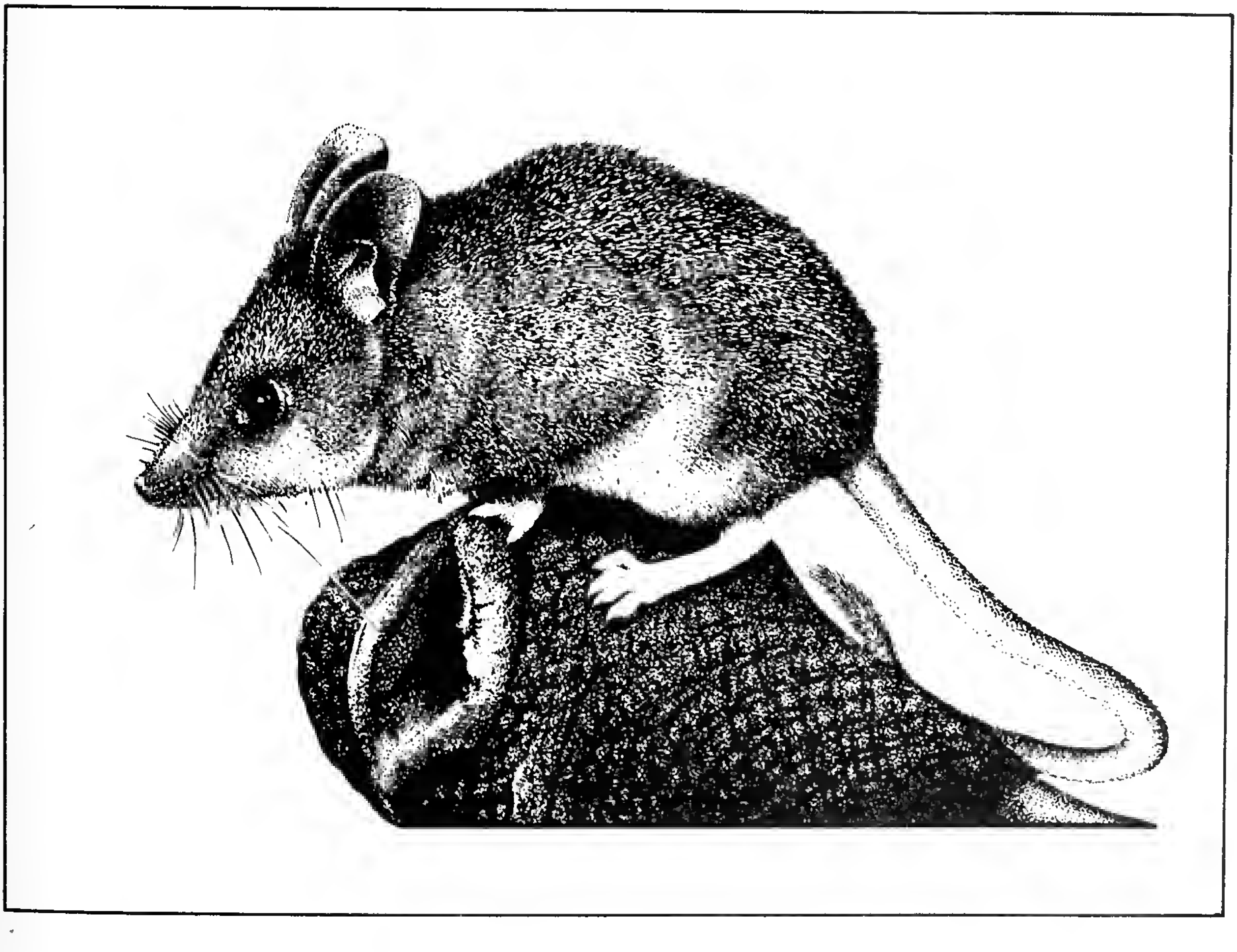

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A Taxonomic Revision of the *Sminthopsis murina* Complex (Marsupialia, Dasyuridae) in Australia, including Descriptions of Four New Species

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Abstract

Sminthopsis murina (sensu, Archer 1981) comprises five species: Sminthopsis murina (Waterhouse, 1838) is redefined and four new species *(S. dolichura, S. gilberti, S. griseoventer, S. aitkeni)* are described on morphological criteria. A system of species indentification for individuals using these criteria is provided through discriminant analysis.

Phenetic and phylogenetic analyses of skull and body morphology for 25 geographic groupings only partly support this taxonomic classification. The reasons for the lack of congruence between these classifications and those of traditional mammalian taxonomy are discussed.

Introduction

The small carnivorous marsupial *Sminthopsis*, differs from other dasyurid genera by possession of the following combination of characters (Archer 1981): squamosal – frontal bones contact on the side wall of the brain case; false palate has vacuities within the palatine bones; nasals only slightly expanded posteriorly; upper molars lack posterior cingula; third premolars only slightly reduced or subequal in size to P2; I^4 longer crowned than I^2; metacristids and hypocristids are transverse to the long axis of the lower checktooth row; supratragus of external ear curled, and narrow hind feet with reduced postinterdigital pads.

Resolution of the taxonomic status of all forms within *Sminthopsis* will not be an easy task. This is a legacy of the fact, noted first by Thomas (1888), that the smaller species of this genus present 'unusual difficulty in their discrimination' because of 'the close resemblance existing between the skulls and teeth of different species.' Archer (1981) clearly recognised this difficulty; in addition to recognising twelve species of *Sminthopsis*, he drew attention to several populations that may prove to be unique. Archer also noted that most species of *Sminthopsis* exhibit geographic variation. In the case of *S. murina* (Waterhouse, 1838), he considered the variation to be clinal, and synonymised *S. murina albipes* (Waterhouse, 1842), *S. murina fuliginosa* (Gould, 1852), and *S. murina tatei* Troughton, 1965 with *S. murina*. However, he employed these names to 'qualify the form of the species occurring in the vicinity of the type locality or having the particular morphological form' but emphasised that his use of these names was not to be interpreted as recognition of their subspecific status (Archer 1981: 94). He considered that *S. murina 'fuliginosa'* occupied Western

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Australia and South Australia west of the Flinders Range; the typical form was to the east of this Range up to approximately 28°S; *S. murina 'tatei'* was restricted to north-eastern Queensland; and that a fourth form, allied to *S. murina 'fuliginosa',* occupied Kangaroo I., South Australia. He did not recognise *S. murina albipes* as distinct from the typical form.

Recent collections from south-western Western Australia gave rise to the suspicion that some of the morphological variation noted by Archer (1981), such as body size, presence or absent of entoconids on M_{1-4}, premolar and molar row lengths, was not clinal but rather indicative of different taxa. Subsequent electrophoretic study of *S. murina* (*sensu* Archer 1981) supports this belief (Baverstock in press.).

Currently, the principles of mammalian taxonomy largely follow the biological species concept (Mayr, 1963), but use a variety of procedures to transform systematic data into classifications. While the biological species concept stresses the isolation of gene pools, different classificatory procedures attempt to recognise this isolation through different criteria. In this paper we primarily employ the traditional approach of mammalian taxonomists in seeking to find disjunct characteristics of morphology which indicate a lack of gene flow between taxa. However, we contrast this traditional taxonomy with a numerical study of morphometric characters which employs both phenetic and phylogenetic analyses after an examination of the statistical properties, primarily covariation, of these characters. This appraisal includes all representatives of *S. murina* (*sensu* Archer, 1981) available to us[1].

Methods

Twenty-two measurements of skull characters and six of external body characters, including weight, were recorded from 131 sexed adult *Sminthopsis* listed under Specimens Examined for each species. Our description follows the terminology of Archer (1981). Cranial and external points used for measurements also follow Archer (1981). Abbreviation for these measurements, in millimetres, are as follows: MAXL, maximum skull length; BASCRANL, basicranial length; MSKW, maximum skull width, MSKH, maximum skull height, ZYHT, zygomatic height measured at the mid-point of the squamosal; BUL, bullae length; OBUL, outside bullae distance; INBUL, inside bullae distance; $C^{\underline{1}}$-$M^{\underline{4}}$, $M^{\underline{1}}$-$M^{\underline{4}}$, $M^{\underline{1}}$-$M^{\underline{3}}$, $I_{\overline{1}}$-$M_{\overline{4}}$, $M_{\overline{1}}$-$M_{\overline{3}}$ crown lengths; LM^{3}-RM^{3}, width outside crowns; INORB, minimum interorbital width; IPVAC, inter-palatal vacuity distance; NASL, nasal length; CRANW, cranial width; DCI_{1}, dentary condyle to $I_{\overline{1}}$; ANGCON, tip of angular process to articular condyle; CONRAM, articular condyle to anterior border of ascending ramus; WT, weight in grams; NV, nose to vent; TV, tail tip to vent length; HF, hind foot length; EAR, ear height from notch; TRAG, tragus height. Colour pelage, when capitalised, follows Ridgway (1912).

Specimens were regarded as adult if M^{4} were fully erupted. Only adults were included in our statistical appraisal.

Univariate statistics. Means and standard deviations were computed for all skull and external body characters and weight. The latter variable was not employed in systematic analyses because it was absent from many animal records.

Preservation of biological specimens may alter external morphology. Because some of the specimens dealt with in this study were treated differently prior to measurement, we compared, for each species, external measurements taken from live animals with those from

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[1] Type specimens for all but *S. murina tatei* are lodged in the British Museum (Natural History) and are not available for loan.

specimens preserved in ethyl alcohol. This comparison using T-tests and a pooled variance estimate, revealed no consistent differences for any variables. Therefore measurements from both live animals and preserved specimens are grouped together. Comparisons between sex and species groups were performed with a two-way analysis of variance.

Multivariate statistics. Principal components analysis, employing an orthogonal solution without iteration, and discriminant analysis, using the criterion of maximising Wilk's Lambda, were performed from SPSS routines (Nie *et al.* 1975) on the Western Australian Regional Computing Centre's Cyber 170-720.

Phenetic and cladistic analyses were carried out on a geographic grouping of specimens. These geographic groupings correspond to the major Structural Elements of the 'BMR Earth Science Atlas of Australia' (Canberra, 1979). The Western Australian Structural Elements are further subdivided according to the phytogeographic regions of Beard (1980). Cladistic analysis used the Wagner 78 programme as supplied by J.S. Farris, State University of New York at Stony Brook. Raw population means of the geographic groupings, hereafter referred to as operational taxonomic units or OTU's, were used as characters and Wagner trees rooted either through the mid-point of the branch connecting the two most divergent OTU's, or with outgroups. *Ningaui ridei*, *Sminthopsis granulipes*, *S. crassicaudata* and *S. macroura* were used either singly or in groups as outgroups. In an attempt to transform the continuous morphometric variables into characters more akin to the discrete genes controlling their expression, means were ranked in ascending order and those separated by less than one average standard deviation grouped. Groupings were then coded in an additive binary fashion (Sneath and Sokal 1973) and these characters used to generate additional Wagner trees as alternatives to those produced from raw means.

As a further alternative to the above trees, Wagner analysis was performed using a data set comprised of the original variables transformed in an attempt to produce size-free values. This transformation consisted of regressing raw values against MAXL (this variable showed the highest loading on the 'size factor' of the factor analysis when averaged for males and females) over the entire data set and then using residuals to characterise individuals (Humphries *et al.* 1981).

Registration numbers of specimens from the Western Australian Museum (WAM), South Australian Museum (SAM) and Australian Museum (AM) are prefixed by M. Specimens from the National Museum of Victoria, Queensland Museum, CSIRO Wildlife Reasearch Collections, and British Museum of National History collection are prefixed by C, J, CM and BM (NH) respectively.

The specimens examined are listed by regional groupings which are located in Figure 3; those not judged adult are denoted by J in parenthesis after the specimen number. (S) and (K) indicate skin and skull respectively; all other specimens have body in alcohol and skull separate.

Systematics

Sminthopsis murina (Waterhouse, 1838)

(Figures 1, 2a; Table1)

Phascogale murina Waterhouse 1838, Proc. Zool. Soc. (Lond.) **5:** 76. North of Hunter's River, N.S.W.

Phascogale albipes Waterhouse 1842, Proc. Zool. Soc. (Lond.) **10:** 48. Port Adelaide, South Australia.

Sminthopsis murina tatei Troughton 1965, Proc. Linn. Soc. *N.S.W.* **89:** 309-321. Tolga, north-east Queensland.

Type specimens: *Phascogale murina* Waterhouse, 1838.

Holotype

British Museum BM (NH) 55.12.24. 95, male, skin and skull. Type locality: Waterhouse (1838: 76) 'Hab. North of Hunter's River, New South Wales.' Thomas (1888: 305), 'Hunter R., N.S.W.' Archer (1981: 84) 'Label on type skin – Hunter's R., N.S.W.'

Diagnosis

Differs from *S. dolichura* as follows (measurements are means, in millimetres): generally shorter tail (77.7 v. 92.8) such that its tail to vent length is less than or only slightly longer than its nose to vent length; a dorsal pelage that is brownish rather than a light fuliginous colour; 10 to eight nipples, whereas *S. dolichura* always has eight; a generally larger skull, particularly maximum length (25.7 v. 25.0). and maximum width (13.7 v. 13.1), longer DC-I_1 (18.6 v. 17.9); wider LM^3-RM^3 (8.1 v. 7.6); M^3 metracristid normally longer rather than shorter than its crown length. Differs from *S. gilberti* as follows: both shorter hind feet (16.7 v. 17.9) and ears (18.1 v. 21.1); a dorsal pelage that is not a light fuliginous colour; *S. gilberti* normally has eight and occasionally six nipples; C^1-M^4 shorter (9.7 v. 10.2); crown height of P^1 and P^3 subequal rather than greater than their length and M^3 metacristid normally longer rather than shorter than its crown length. Differs from *S. griseoventer* as follows: dorsal pelage not a light fuliginous colour and a ventral pelage that is a white rather than a 'grizzled' grey colour; *S. griseoventer* normally has eight and occasionally six nipples; C^1-M^4 shorter (v. 10.2); dP^4 with three major cusps not two as in *S. griseoventer* (StD absent); M^3 metacristid normally longer rather than shorter than its crown length; C_1 normally taller rather than subequal or shorter crowned than P_3; entoconid on M_2 and M_3 absent or small rather than medium to large; and a generally shorter IPVAC (3.3 v. 4.0). Differs from *S. aitkeni* as follows: dorsal pelage not a dark fuliginous colour; a ventral pelage that is white rather than light grey; generally shorter tail (v. 96.0); smaller maximum skull height (7.1 v. 7.7); shorter C^1-M^4 (9.7 v. 10.8); M^3 metacrista normally longer rather than shorter than its crown lenght; C_1 normally taller rather than subequal or shorter crowned than P_3; entoconids on M_2 and M_3 small to absent rather than medium to large; and generally shorter IPVAC (v. 4.2). If the above diagnosis fails to identify a specimen then it may be distinguished from *S. dolichura*, *S. gilberti*, *S. griseoventer* and *S. aitkeni* by the discriminant function analysis presented herein. Differs from other species of *Sminthopsis* in the way that *S. murina* (*sensu* Archer, 1981) differs from these species (see Archer ,1981).

Description

Pelage

Colour varies little over the range of the species. Dorsal pelage, including that on forearms and hind feet and sides of the body is Fuscous Black at the base, tipped with a mixture of Hair Brown, Drab and Clay Colour; the dominant dorsal colour depends on which colour at the tip of the hairs predominates – usually it is Clay Colour (light brown). The head and neck is a darker Saccardo's Umber which does not extend to the face, apart from small patches around the eyes. Colour of the face and cheeks is that of the predominant dorsal colour, usually Clay Colour. Small lighter coloured patches of Olive Buff to Vinaceous Buff behind the ears. Hairs of the underparts are Deep Violet Gray for the basal half or two-thirds and tipped with white – which is the overall colour. Pes, manus and ventral fur of forearm is white. The dorsal and ventral surfaces of the tail are the colour of their respective body pelage surfaces.

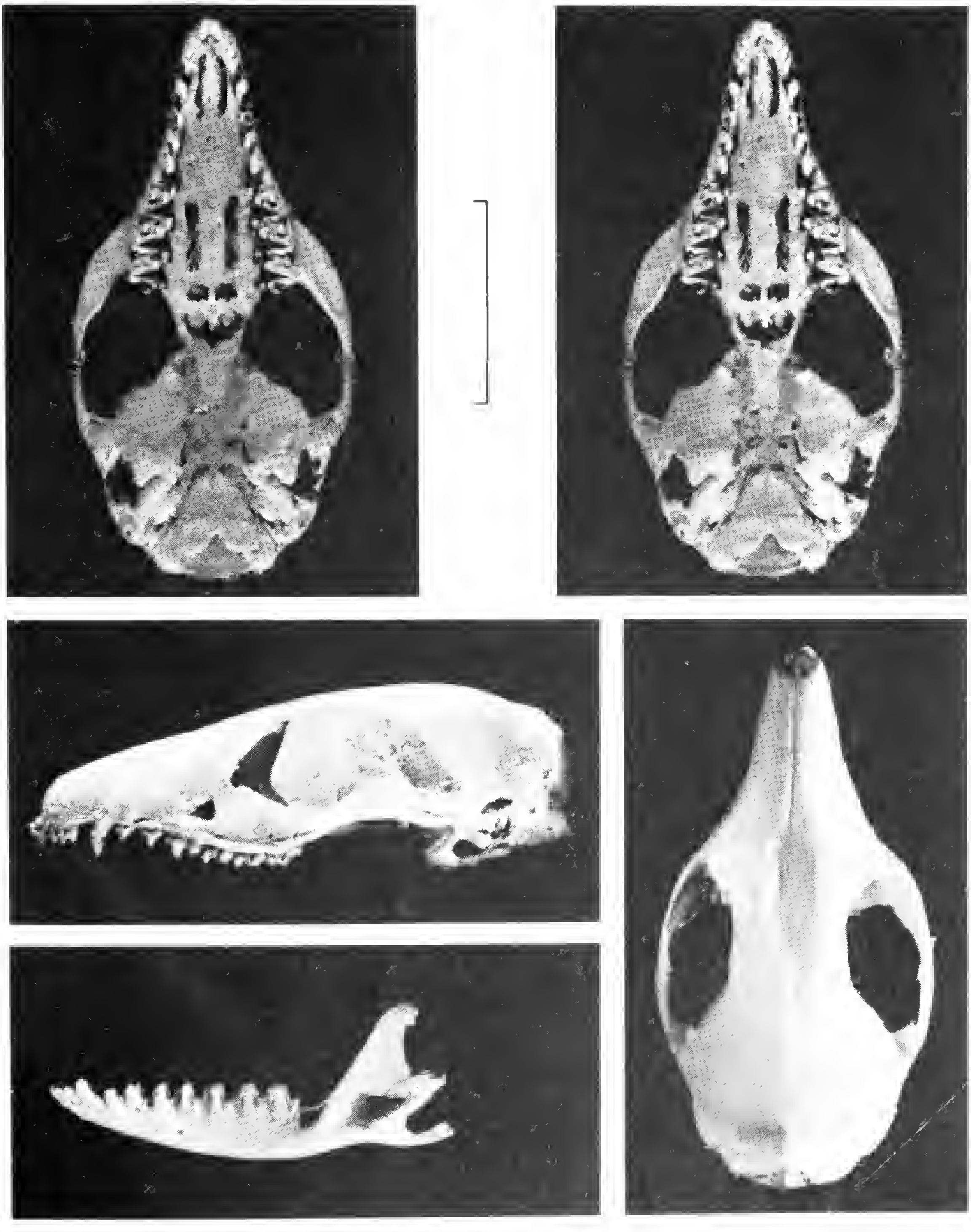


Figure 1 Skull and left dentary of *S. murina*, AM M6753. The ventral aspects of the skull are stereopairs, scale line, 10 mm.

Tail

Tail to vent length averages 77.7, which is slightly shorter than the average nose to vent length of 79.3. Tail invariably thin.

Hind foot

Interdigital pads fused near their base; each pad covered with granules with a medial anteroposterior row of enlarged granules which generally increase in size anteriorly. The apical granule of the fourth interdigital pad frequently the largest and often fused with its proximal granule. In J16475, Mt Molloy, north-eastern Queensland, the apical and proximal granules of the second interdigital pad are also fused; apparent striae frequently present on enlarged granules. Hallucal granules always present; Metatarsal granules absent. Post hallucal granule rarely present. In J21317, Mt Molloy, north-eastern Queensland, two small post hallucal granules fuse to form a small rectangular pad.

Nipple Number

Krefft (1867) stated that *Antechinus albipes* (considered by us and Krefft [1867] to be *S. murina*) were 'common on the lower Murray and near Sydney, (and) has ten mammae in the pouch.' Of the specimens examined by us, those from Mt Molloy, north-eastern Queensland, had eight (N = 7) or six (N = 1) nipples, while those from other parts of their distribution had ten (N = 4) or eight (N = 2) nipples.

Dentition

I^1 taller-crowned than I^2; I^2 generally shorter-crowned than I^3 but occasionally subequal; I^4 generally subequal but sometimes larger-crowned than I^3; width of $I^2 < I^3 < I^4$. C^1 usually caniniform but occasionally (e.g. C15791) slightly premolariform, conspicuously taller crowned than P^1; C^1 crown usually taller than P^4 but occasionally subequal. Crown height P^1 and P^3 longer than their crown length; P^4 taller than its crown length; crown height $P^4 < P^3 > P^1$; premolar size generally increases gradually posteriorly; anterior and posterior cingular cusps on P^1 to P^4 small to moderate, with posterior cusp usually larger than anterior cusp; buccal and lingual cingula slight and frequently absent on P^4; postero-lingual cingulum frequently slightly enlarged on P^3. dP^4 (e.g. C15891) has three roots and three main cusps: a paracone, a subequal or slightly shorter stylar cusp D, and a taller metacone; protocone low and rudimentary; two tiny cusps on the anterobuccal cingulum variably present and may represent StA and StB; metacristid variably developed but obvious. Anterior cingula on M^1 to M^4 confined to the anterobuccal corner. StC slight to moderate and frequently present on M^3 only. StE small to moderate, occasionally present on M^3 and rarely present on M^1 and M^2. Metacrista of M^3 usually longer or subequal to, rarely shorter than, its crown length. Diastema between C_1 and I_4. Contact between C_1 and I_4 variable. Usually no contact between P_1, P_3 and P_4 but contact between P_4 and M_1 variable. C_1 premolariform, usually its crown higher than that of P_3 although rarely subequal. Crown heights of P_1, P_3 and P_4 variable: most commonly they increase from P_1 to P_4, although frequently P_3 tallest with P_4 taller or subequal to P_1. Moderate posterior cingular cusps on P_1 to P_4 and C_1; smaller anterior cingular cusps on P_1 to P_4 in all but most worn teeth. Narrow buccal and lingual cingula usually present on P_1 and P_3, occasionally on P_4. C_1 with narrow lingual cingulum and occasionally a narrow buccal cingulum. I_4 with moderate-sized posterior lobe, absent from I_3 to I_1. dP_4 (e.g. C15891) has two roots and one main cusp – the protoconid; posterior flank of protoconid with variably developed minor cusp – possibly a metaconid. Posterior cingular cusp connected to metaconid of $dP_{\overline{4}}$ by a crest. Parastylids present on $M_{\overline{2}}$-$_{\overline{4}}$ but absent from $M_{\overline{1}}$. Entoconids commonly absent but when present tiny or small and usually on $M_{\overline{2}}$ and $M_{\overline{3}}$. Talonid wider than trigonid only on $M_{\overline{1}}$. Anterior cingula on M_1 to $M_{\overline{4}}$, and posterior cingula on $M_{\overline{1}}$ to $M_{\overline{3}}$ narrow; cingula always absent at base of protoconid. Paraconid smaller than or subequal to metaconid on $M_{\overline{4}}$.

Skull and Dentary

Nasals expand slightly posteriorly. Frontals with shallow mesial depressions. Lacrimal foramina on or just posterior to anterior rim of orbit. Length of premaxillary vacuity variable but normally extends posteriorly to a point level with cusp of P^1, rarely only to anterior root of P^1; maxillary vacuity varies in length but generally extends anteriorly to a point level with anterior edge of M^1, but frequently to a point level with posterior root of P^4. Minimal to absent dorsolateral expansion of lacrimal rim over orbit. Alisphenoid bulla small, broadly exposing ectotympanic ring. Mastoid process uninflated. Periotic bulla small. Foramen pseudovale large. Alisphenoid bar between sphenorbital foramen and foramen rotundum usually moderate, but in several specimens (e.g. CM147) is so wide that laterally the internal openings of foramen rotundum completely obscured. Anterior border of ascending ramus and posterior edge of dentary divergent: distance between articular condyle and tip of ascending ramus shorter than distance between articular condyle and tip of angular process.

Distribution and Habitat

Sminthopsis murina is widely distributed in eastern Australia, mostly in areas receiving an annual median rainfall in excess of 600 mm, but occasionally in areas receiving between 300-400 mm. In south Australia it is not known from localities west of the Flinders Ranges (Figure 3).

Archer (1981) has reviewed the habitat of *Sminthopsis murina (sensu stricto).* As with *S. dolichura, S. gilberti and S. griseoventer,* it occupies a wide range of habitats including open woodland and sclerophyll forest, wet fringes close to rainforest, grasslands and partly cleared land.

Remarks

Other holotypes from within the range of *S. murina* are *Sminthopsis murina tatei* and possibly *Sminthopsis albipes.* There is some doubt as to the type locality of *S. albipes.* Waterhouse (1842) gives it as 'Port Adelaide.' However, Thomas (1888: 305) states that this locality appears to mean the southern part of Australia, i.e. Victoria. Iredale and Troughton (1934: 10) give Port Adelaide or Port Lincoln, South Australia, as possible localities; Archer (1981) reports that the label attached to the holotype states 'South Australia.' The type locality of *Sminthopsis murina tatei* is given by Troughton (1965: 3, 6) as 'Tolga on the Atherton Tableland, at approximately 2,460 ft, north-eastern Queensland.'

The description of the holotype of *S. albipes,* particularly the reference to a brownish pelage on the upper parts of the body and the tail being considerably shorter than the length from snout to base of tail (± 81.3 cf. 99.1 mm) are applicable to *S. murina* in South Australia and not *S. dolichura* or *S. aitkeni.* Furthermore, illustrations of the holotype (Archer [1981] Figure 14) show entoconids to be very small or absent; the cranial measurements he presents are also within the range for *S. murina.* The dark colour of the tail of *S. albipes* referred to by Waterhouse in his type description as a feature which distinguishes *S. albipes* from *S. murina,* is not considered by us to be diagnostic for any of the species discussed herein. For these reasons we follow Archer (1981), Tate (1947), Thomas (1888) and Krefft (1867) in not recognising *albipes* as a form distinct from *S. murina.*

Sminthopsis murina tatei is stated by Troughton (1965) to have a larger pes and longer tail than any intermediate mainland form of *S. murina* but that 'its dimensions are in general agreement with *fuliginosa*.' Archer (1981) examined an extensive series of specimens from Mt Molloy, north-east Queensland, approximately 64 km north of the type locality of *S. murina tatei,* which is at Tolga, including specimens closely resembling those mentioned by Tate (1947) and Troughton (1965) as *S. murina tatei.* Archer concluded that 'no cranial or dental characters are found to consistently separate *tatei* from *fuliginosa*.' We examined the same series from Mt Molloy and discuss this form in the General Discussion.

Specimens Examined

Hodgkinson Fold Belt group (HFB)

Tolga, 17°13'S, 145°29'E, 1♂, AM M7157 (holotype *S. murina tatei*). Mt Molloy, 16°41'S, 145°20'E, 4♂, 7♀, J16648, J16475, J16647, J1013, J16478, J16476, J16479, J15896, J15895, J21316, J21317.

New England Fold Belt group (NEF)

Wallaby Ck, 28°37'S, 152°25'E, 4♂, CM143(S), CM145, CM558, CM147. 5 km E Deepwater, 29°26'S, 151°51'E, 1♂ CM8993. Queens Lake State Forest, 31°38'S, 152°44'E, 2♂, AM M11441, AM M10862. Rockhampton, 23°22'S, 150°32'E, 1♂, J.1472. Nr Brisbane, 27°28'S, 153°01'E, 1♂, AM.M8565. 12 km S Dungowan, 31°20'S, 151°07'E, 1♂, SAM M9409. Dungowan, 31°13'S, 151°07'E, 1♀, SAM M9690.

Clarence-Moreton Basin group (CMB)

Bundylung Res., 29°07'S, 153°26'E, 1♀, CM3732 (S), Mt Brown, 28°30'S, 152°30'E, 1♂, CM382 (S).

Sydney Basin group (SYB)

Kurrajong, 33°34'S, 150°40'E, 2♂, AM M6639, AM6753.

Surat Basin group (SB)

Pillaga Scrub via Coonabarabram, 30°21'S, 148°53'E, 1♂, CM3926 (S).

Lachlan Fold Belt group (LFB)

Gundaroo, 35°02'S, 149°16'E, 1♂, CM6019 (S). Nr Mt Buninyong, 37°39'S, 143°56'E, 1♀, C15891 (j). Kinglake Nat. Pk, 37°30'S, 145°18'E, 1♀, C12644. Christmas Hills, 37°39'S, 145°19'E, 1♀, C14022. Murrumbateman, 34°58'S, 149°02'E, 1♀, CM6011. 15 km SW Edenhope, 37°02'S, 141°17'E, 1♂, C24357. Fraser Nat. Pk, 37°12'S, 146°00'E, 1♂, C13942. Buxton, 37°25'S, 145°43'E, 1♂, C23173. 15 km N. Casterton, 37°00'S, 141°24'E, 1♂, C14020 (S).

Otway Basin group (OB)

Bannockburn, 38°03'S, 144°10'E, 1♀, C15791. Big Heath Nat. Pk, 37°05'S, 140°40'E, 1♂, SAM M7682.

Murray Basin group (MB)

25 km W Rainbow, 35°43'S, 141°30'E, 1♀, C14027 (S). 4 km W Jumby East Dam, 35°56'S, 139°42'E, 1♀, SAM M10896. Haylands, 34°14'S, 139°38'E, 1♀, SAM M10251. Victor Harbour, 35°33'S, 138°37'E, 1♀, SAM M7536 (S). Billiatt Nat. Pk (NW), 34°55'S, 140°30'E, 1♀, SAM M8636 (S). Birthday Tank. 34°54'S, 141°36'E, 1♂, C10920. 1.7 km N Birthday Tank, 34°47'S, 141°36'E, 1♂, C15826.

Table 1 Skull and body characters for the five species of *Sminthopsis*. Values are means, with standard deviations in bold and sample size in brackets for (a) males, (b) females.

(a) Males

Character	*S. murina*	*S. dolichura*	*S. gilberti*	*S. griseoventer*	*S. aitkeni*
MAXL	26.38 **1.30**(26)	25.23 **0.90**(49)	27.59 **0.72**(10)	26.66 **0.98**(21)	27.97 **1.27**(3)
BASCRANL	23.95 **1.36**(26)	23.08 **0.98**(49)	25.07 **0.59**(9)	24.11 **0.98**(21)	24.75 **1.77**(2)
MSKH	7.26 **0.31**(26)	6.87 **0.22**(49)	7.41 **0.20**(10)	7.42 **0.25**(21)	7.85 **0.35**(2)
MSKW	14.22 **1.06**(24)	13.19 **0.71**(50)	14.77 **0.62**(10)	14.30 **0.74**(21)	14.30 **0.56**(3)
ZYHT	1.40 **0.25**(26)	1.20 **0.18**(50)	1.39 **0.16**(10)	1.36 **0.17**(20)	1.33 **0.15**(3)
BUL	5.04 **0.19**(26)	5.25 **0.18**(50)	5.17 **0.19**(9)	5.00 **0.14**(19)	4.95 **0.21**(2)
OBUL	9.35 **0.45**(26)	9.16 **0.34**(49)	9.93 **0.35**(8)	9.59 **0.44**(15)	9.75 **0.64**(2)
INBUL	3.31 **0.30**(25)	3.08 **0.21**(48)	3.66 **0.15**(7)	3.42 **0.25**(12)	3.70 **0.14**(2)
C^1-M^4	9.85 **0.45**(26)	9.42 **0.31**(50)	10.38 **0.22**(10)	10.34 **0.34**(20)	11.03 **0.47**(3)
M^1-M^4	5.27 **0.17**(26)	5.18 **0.14**(50)	5.56 **0.16**(10)	5.40 **0.16**(21)	5.80 **0.17**(3)
M^1-M^3	4.60 **0.17**(26)	4.51 **0.13**(50)	4.88 **0.18**(10)	4.76 **0.15**(21)	5.13 **0.15**(3)
LM^3-RM^3	8.20 **0.54**(26)	7.57 **0.26**(50)	8.34 **0.36**(10)	8.18 **0.40**(21)	8.37 **0.35**(3)
INORB	5.01 **0.36**(26)	4.97 **0.23**(50)	5.44 **0.22**(10)	5.05 **0.21**(21)	5.47 **0.32**(3)
IPVAC	3.51 **0.51**(26)	2.99 **0.33**(50)	3.44 **0.36**(8)	4.21 **0.32**(15)	4.40 **0.20**(3)
NASL	9.77 **0.82**(26)	9.20 **0.61**(50)	10.60 **0.70**(10)	9.38 **0.67**(21)	10.00 **0**(3)
CRANW	10.38 **0.57**(26)	9.96 **0.35**(50)	10.80 **0.63**(10)	10.86 **0.57**(21)	10.67 **0.58**(3)
DC-I_1	19.17 **1.14**(26)	18.16 **0.76**(50)	20.23 **0.53**(9)	19.40 **0.86**(21)	20.33 **1.25**(3)
I_1-M_4	11.24 **0.49**(26)	10.73 **0.36**(50)	11.95 **0.33**(10)	11.75 **0.39**(21)	12.57 **0.61**(3)
M_1-M_4	5.64 **0.23**(26)	5.47 **0.14**(50)	5.97 **0.15**(10)	5.82 **0.16**(21)	6.23 **0.15**(3)
M_1-M_3	4.10 **0.21**(26)	4.00 **0.12**(50)	4.45 **0.13**(10)	4.30 **0.16**(21)	4.63 **0.21**(3)

(a) **Males** (continued)

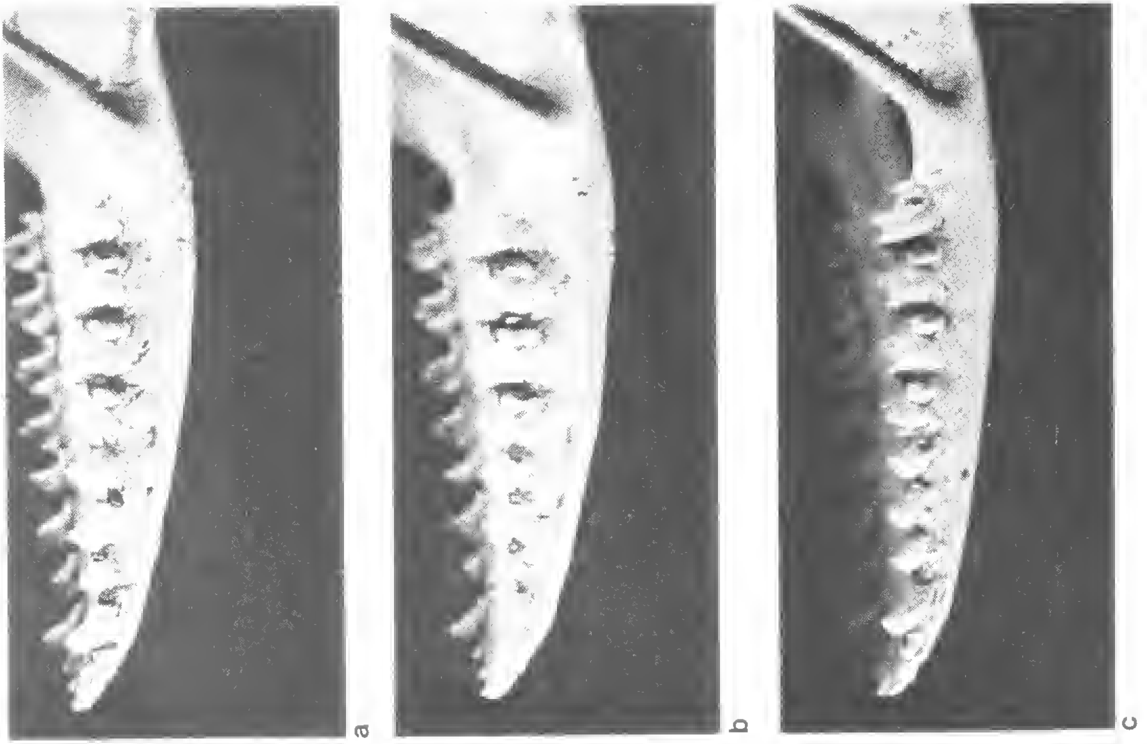
Character	*S. murina*	*S. dolichura*	*S. gilberti*	*S. griseoventer*	*S. aitkeni*
ANGCON	5.26 **0.33**(26)	5.14 **0.24**(50)	5.34 **0.23**(8)	5.42 **0.24**(20)	5.30 **0.40**(3)
CONRAM	4.33 **0.45**(26)	4.16 **0.31**(50)	4.43 **0.24**(9)	4.64 **0.33**(21)	4.43 **0.21**(3)
WT	19.54 **3.34**(8)	13.68 **3.07**(35)	21.75 **6.01**(2)	17.20 **4.34**(5)	30.5 **0**(1)
NV	81.22 **8.67**(25)	74.47 **6.75**(50)	89.73 **6.43**(10)	86.58 **8.39**(19)	88.37 **4.51**(3)
TV	78.88 **9.08**(25)	94.61 **7.22**(50)	83.25 **7.59**(10)	83.16 **5.14**(20)	98.20 **7.60**(3)
HF	17.11 **0.89**(25)	16.83 **0.68**(50)	18.13 **0.85**(10)	16.59 **1.18**(20)	17.50 **1.08**(3)
EAR	18.34 **1.09**(25)	19.66 **1.34**(48)	21.38 **1.05**(10)	18.06 **1.59**(20)	18.37 **0.45**(3)
TRAG	3.29 **0.40**(21)	3.34 **0.40**(47)	3.20 **0.21**(5)	3.22 **0.35**(9)	3.60 **0**(1)

(b) **Females**

Character	*S. murina*	*S. dolichura*	*S. gilberti*	*S. griseoventer*	*S. aitkeni*
MAXL	24.76 **1.12**(17)	24.43 **0.96**(26)	26.56 **0.78**(8)	25.77 **0.92**(11)	26.35 **0.35**(2)
BASCRANL	22.29 **1.14**(18)	22.16 **0.94**(25)	24.00 **0.81**(8)	23.16 **1.13**(12)	23.70 **0.28**(2)
MSKH	6.86 **0.17**(18)	6.65 **0.27**(27)	7.21 **0.84**(8)	7.23 **0.18**(12)	7.60 **0.42**(2)
MSKW	13.02 **0.80**(16)	12.80 **0.75**(26)	13.97 **0.61**(7)	13.65 **0.62**(11)	13.80 **1.13**(2)
ZYHT	1.31 **0.15**(17)	1.20 **0.18**(28)	1.37 **0.17**(7)	1.33 **0.15**(12)	1.40 **0.28**(2)
BUL	4.83 **0.21**(18)	5.10 **0.17**(28)	5.16 **0.19**(5)	4.95 **0.16**(11)	4.90 **0**(2)
OBUL	9.02 **0.39**(18)	8.88 **0.34**(27)	9.55 **0.29**(4)	9.31 **0.28**(10)	9.55 **0.35**(2)
INBUL	3.28 **0.22**(17)	3.03 **0.21**(27)	3.30 **0.26**(3)	3.43 **0.27**(10)	3.70 **0.28**(2)

(b) Females (continued)

Character	*S. murina*	*S. dolichura*	*S. gilberti*	*S. griseoventer*	*S. aitkeni*
$C^{\underline{1}}$-$M^{\underline{4}}$	9.41 **0.42**(18)	9.21 **0.32**(28)	10.08 **0.18**(8)	10.00 **0.34**(12)	10.45 **0.07**(2)
$M^{\underline{1}}$-$M^{\underline{4}}$	5.24 **0.21**(18)	5.16 **0.16**(28)	5.59 **0.08**(8)	5.43 **0.14**(12)	5.50 **0.28**(2)
$M^{\underline{1}}$-$M^{\underline{3}}$	4.61 **0.22**(18)	4.50 **0.15**(28)	4.93 **0.07**(8)	4.80 **0.14**(12)	4.85 **0.07**(2)
$LM^{\underline{3}}$-$RM^{\underline{3}}$	7.93 **0.42**(17)	7.61 **0.40**(28)	8.15 **0.20**(8)	8.12 **0.41**(12)	8.20 **0.57**(2)
INORB	4.62 **0.28**(18)	4.77 **0.25**(28)	5.23 **0.17**(8)	4.87 **0.20**(12)	5.25 **0.21**(2)
IPVAC	3.05 **0.38**(17)	2.96 **0.49**(28)	3.06 **0.35**(7)	3.77 **0.44**(10)	3.95 **0.50**(2)
NASL	8.89 **0.58**(18)	8.57 **0.50**(28)	10.00 **0.53**(8)	9.27 **0.47**(11)	9.50 **0.71**(2)
CRANW	9.78 **0.43**(18)	9.71 **0.53**(28)	10.50 **0.53**(8)	10.50 **0.52**(12)	10.50 **0.71**(2)
DC-I_1	17.85 **0.97**(18)	17.53 **0.80**(28)	19.25 **0.73**(8)	18.41 **0.69**(11)	19.00 **0.42**(2)
$I_{\overline{1}}$-$M_{\overline{4}}$	10.73 **0.48**(18)	10.51 **0.39**(28)	11.65 **0.17**(8)	11.35 **0.41**(11)	11.85 **0.07**(2)
$M_{\overline{1}}$-$M_{\overline{4}}$	5.63 **0.25**(18)	5.45 **0.23**(28)	5.95 **0.09**(8)	5.87 **0.14**(12)	5.95 **0.07**(2)
M_1-$M_{\overline{3}}$	4.06 **0.22**(18)	4.01 **0.13**(28)	4.39 **0.06**(8)	4.35 **0.13**(12)	4.45 **0.07**(2)
ANGCON	5.08 **0.30**(16)	5.09 **0.30**(27)	5.24 **0.21**(8)	5.21 **0.21**(12)	5.20 **0**(2)
CONRAM	3.98 **0.44**(18)	4.01 **0.32**(28)	4.14 **0.29**(8)	4.34 **0.30**(11)	4.25 **0.21**(2)
WT	14.33 **4.20**(7)	13.44 **3.38**(16)	13.75 **1.77**(2)	19.45 **2.76**(2)	0
NV	76.23 **9.49**(15)	73.67 **7.16**(27)	81.05 **5.75**(6)	77.67 **9.38**(9)	**84.75** **10.54**(2)
TV	75.65 **4.83**(15)	89.57 **7.31**(28)	75.23 **10.11**(6)	80.38 **4.47**(11)	92.65 **1.91**(2)
HF	15.97 **0.81**(15)	16.37 **0.99**(28)	17.53 **1.64**(6)	15.71 **0.79**(10)	17.55 **0.78**(2)
EAR	17.74 **1.68**(14)	18.63 **1.96**(26)	20.63 **0.89**(6)	17.12 **1.29**(10)	17.95 **0.50**(2)
TRAG	3.36 **0.24**(8)	3.30 **0.49**(24)	3.33 **0.21**(3)	3.13 **0.36**(7)	0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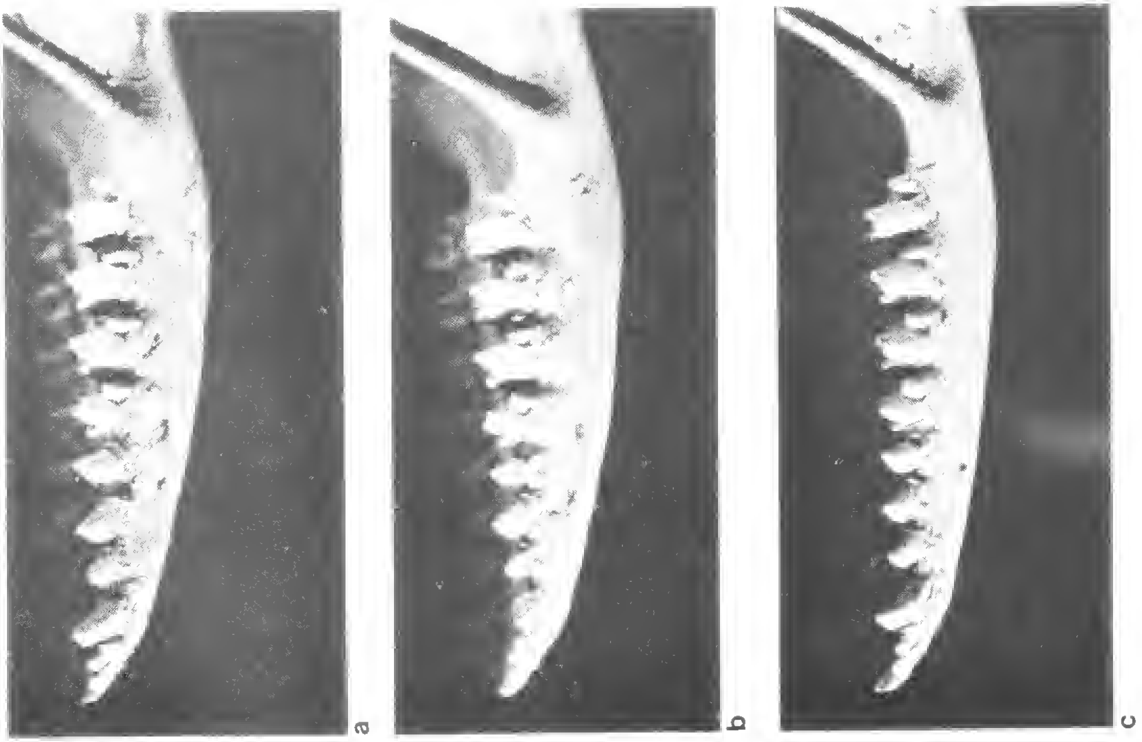
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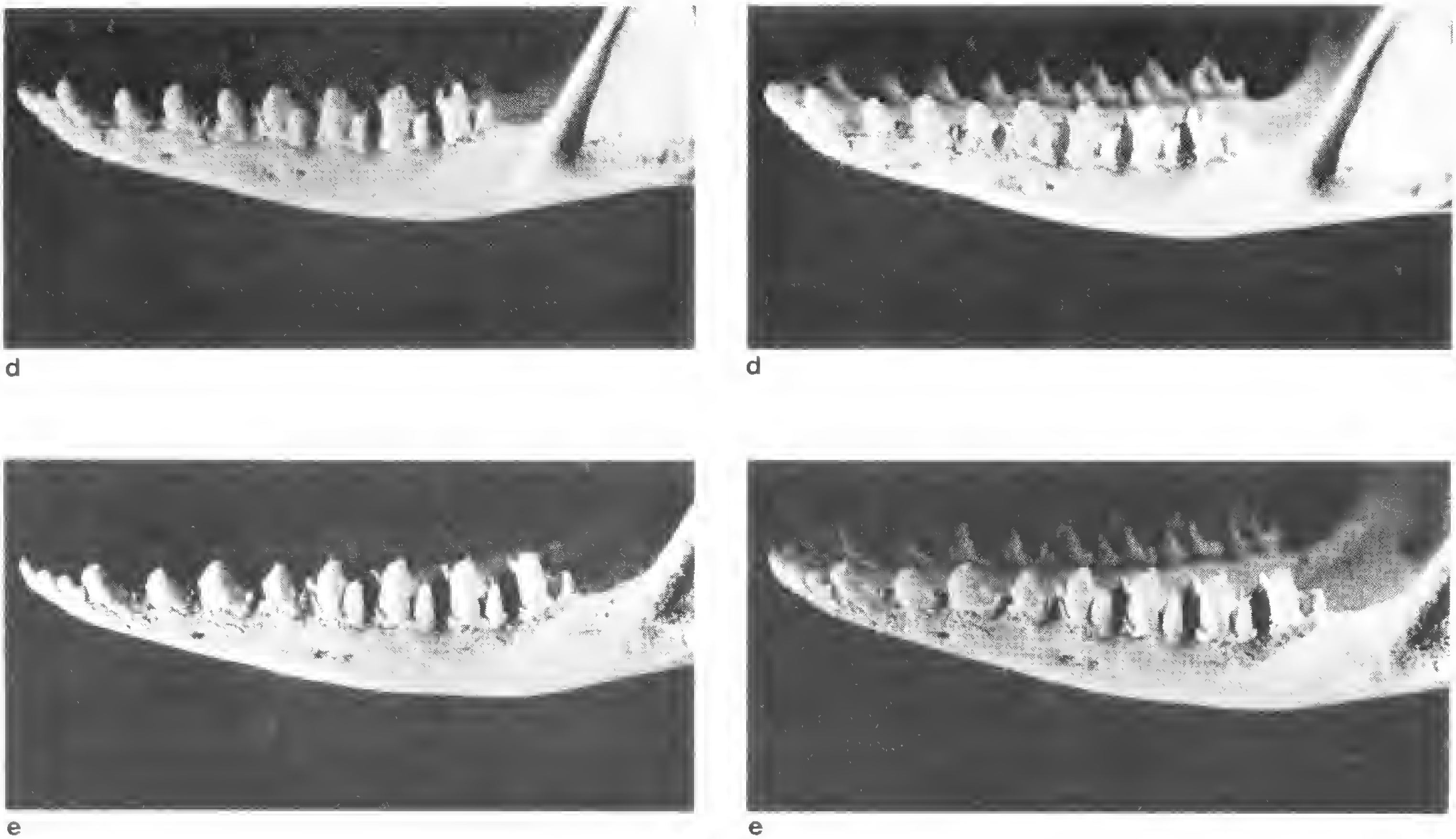

Figure 2 Left dentary from buccal aspect, as stereopairs for:

(a) *S. murina*, AM M6753
(b) *S. dolichura*, holotype
(c) *S. gilberti*, holotype
(d) *S. griseoventer*, holotype
(e) *S. aitkeni*, holotype.

Scale line, 5 mm.

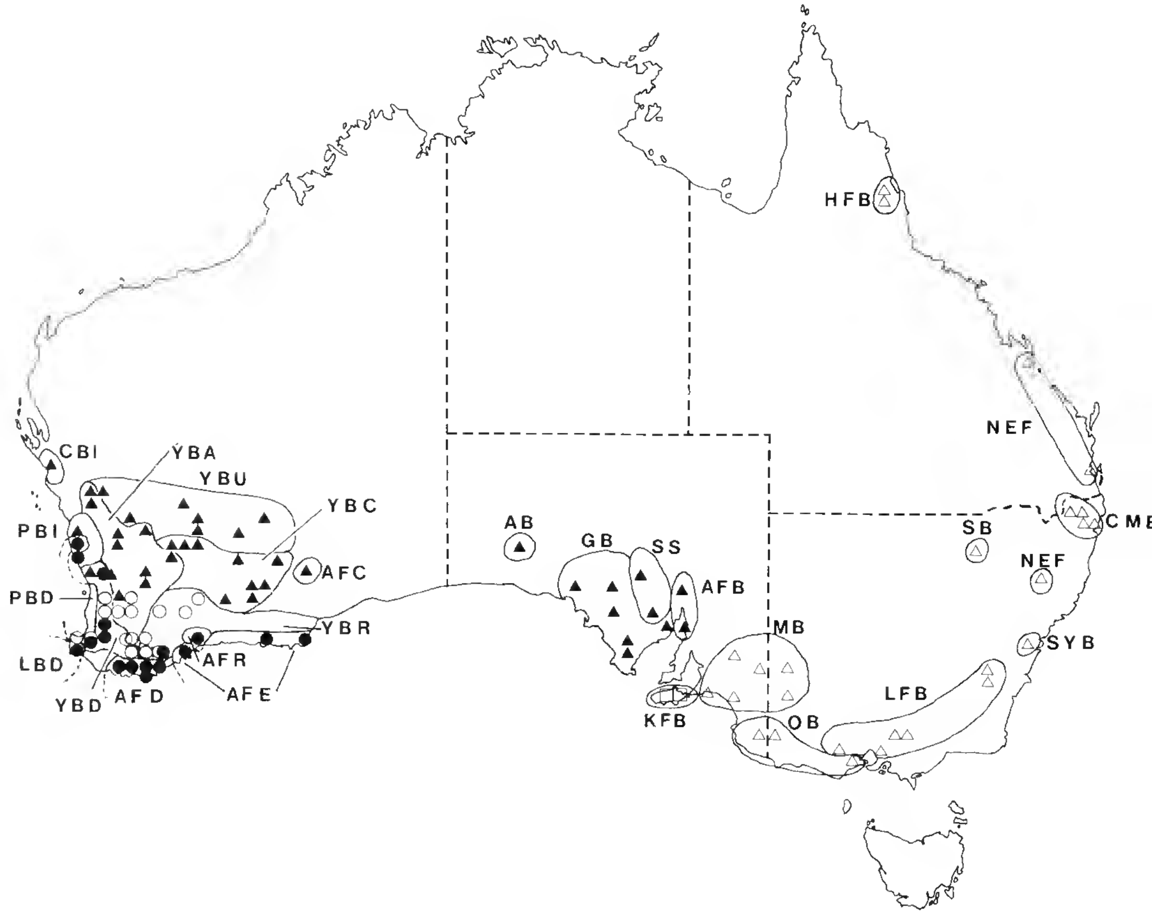

Figure 3 Allocation of *S. murina* (△), *S. dolichura* (▲), *S. gilberti* (○), *S. griseoventer* (●), and *S. aitkeni* (□) specimens to geographic groups. HFB, Hodgkinson Fold Belt; NEF, New England Fold Belt; CMB, Clarence-Moreton basin; SB, Surat Basin; SYB, Sydney-Basin; LFB, Lachlan Fold Belt; OB, Otway Basin; MB, Murray Basin; KFB, Kanmantoo Fold Belt; AFB, Adelaide Fold Belt; SS, Stuart Shelf; GB, Gawler Block; AB, Arckaringa Basin; AFC, Albany-Fraser Province/Coolgardie; AFR, Albany-Fraser Province/Roe; AFE, Albany-Fraser Province/Eyre; AFD Albany-Fraser Province/Darling; YBD, Yilgarn Block/Darling; LBD, Leeuwin Block/Darling; PBD, Perth Basin/Darling; PBI, Perth Basin/Irwin; CBI, Carnarvon Basin/Irwin; YBA, Yilgarn Block/Avon; YBU, Yilgarn Block/Austin; YBC, Yilgarn Block/Coolgardie; YBR, Yilgarn Block/Roe.

Sminthopsis dolichura sp. nov.

(Figures 2b, 4a, 5, 6; Table 1)

Holotype

WAM M17985; adult male, skull and dentaries, carcase (liver removed for electrophoresis) in 70% ethyl alcohol. Pit-trapped by R.A. How *et al.* on 15 August 1980, 6 km SSE of Buningonia Spring, Western Australia (31°28′10″S, 123°36′00″E), at 250 m above sea level. Type locality described under Distribution and Habitat.

Paratypes

10 females and 21 males; see Specimens Examined.

Diagnosis

Sminthopsis dolichura differs from *S. murina* as follows (measurements are means, in millimetres): longer tail (92.8 v. 77.7); a dorsal pelage that is a light fuliginous rather than a brownish colour; not more than eight teats; generally smaller skull, particularly maximum length (25.0 v. 25.7) and maximum width (13.1 v. 13.7); shorter DCI_1 (17.9 v. 18.6); narrower LM^3-RM^3 (7.6 v. 8.1); and M^3 metacristid shorter or subequal to, rather than longer than its crown length. Differs from *S. gilberti* as follows: both shorter hind feet (16.7 v. 17.9) and ears (19.3 v. 21.1); longer tail (92.8 v. 80.2); smaller skull, particularly maximum length (25.0 v. 27.1) and maximum width (13.1 v. 14.4); shorter DC-I_1 (17.9 v. 19.8); shorter C^1-M^4 (9.3 v. 10.2) and distance across LM^3-RM^3 (5.5 v. 6.0) and higher CONRAM: I_1-M_4 ratio (0.75 v. 0.72). Differs from *S. griseoventer* as follows: longer tail (v. 82.2); a white rather than a 'grizzled' grey ventral pelage; smaller skull, particularly maximum length (25.0 v. 26.4) and maximum width (13.1 v. 14.1); shorter C^1-M^4 (v. 10.2); dP^4 has three major cusps rather than two; C_1 crown normally taller rather than subequal, or shorter than that of P_3; entoconids on M_2 and M_3 absent or very small rather than moderate or large; shorter IPVAC (3.0 v. 4.0). Differs from *S. aitkeni* as follows: dorsal pelage has a lighter fuliginous colour and its ventral pelage whiter; smaller skull, particularly maximum length (v. 27.3), maximum width (v. 14.1) and maximum height (6.8 v. 7.7); shorter in all tooth dimensions, particularly C^1-M^4 (v. 10.8); C_1 taller rather than subequal or shorter crowned than P_3; entoconids on M_2 and M_3 absent or very small rather than moderate or large. If the above diagnosis fails to identify a specimen then it may be distinguished from *S. murina*, *S. gilberti*, *S. griseoventer* and *S. aitkeni* by the discriminant function analysis presented herein. Differs from other species of *Sminthopsis* in the way that *S. murina* (*sensu* Archer, 1981) differs from them. (See Archer [1981].)

Description

Pelage

Colour varies little over the range of the species. Dorsal fur, including that on forearms and hind feet, and sides of the body Fuscous Black at base, tipped with mixture of Greyish Olive and Black dorsally and occasionally with Light Pinkish Cinnamon laterally. Black tipped hairs more prominent mesially and extend from base of tail anteriorly to forehead. Overall the dorsal pelage is a light fuliginous colour. Apart from thin ring of Black around eye, face and cheeks Light Pinkish Cinnamon, as are small patches behind ears. Ventral fur similar in colour to *S. murina*. Dorsal and ventral surface of tail are the colour of their respective body pelage surfaces.

Tail

Average tail to vent length 92.8, i.e. 25.0% longer than average nose to vent length of 74.2. Tail invariably thin.

Hind Foot

As for *S. murina* except for the following:apical granule of fourth interdigital pad normally the largest and frequently fused with its posterior proximal granule. Small metatarsal granule present in WAM M6998 only. Post hallucal granule rarely present (WAM M17742), and fusion of several such granules to form a small elongate post hallucal pad is recorded only twice (WAM M6998, WAM M17995).

Figure 4 (a) *S. dolichura* (animal still in captivity), note long tail and white underparts (photo. G. Barron).
(b) *S. gilberti* holotype, note relatively short tail, long ears and white underparts (photo. G. Barron).
(c) *S. griseoventer* holotype, note relatively short tail, short ears and greyish underparts.

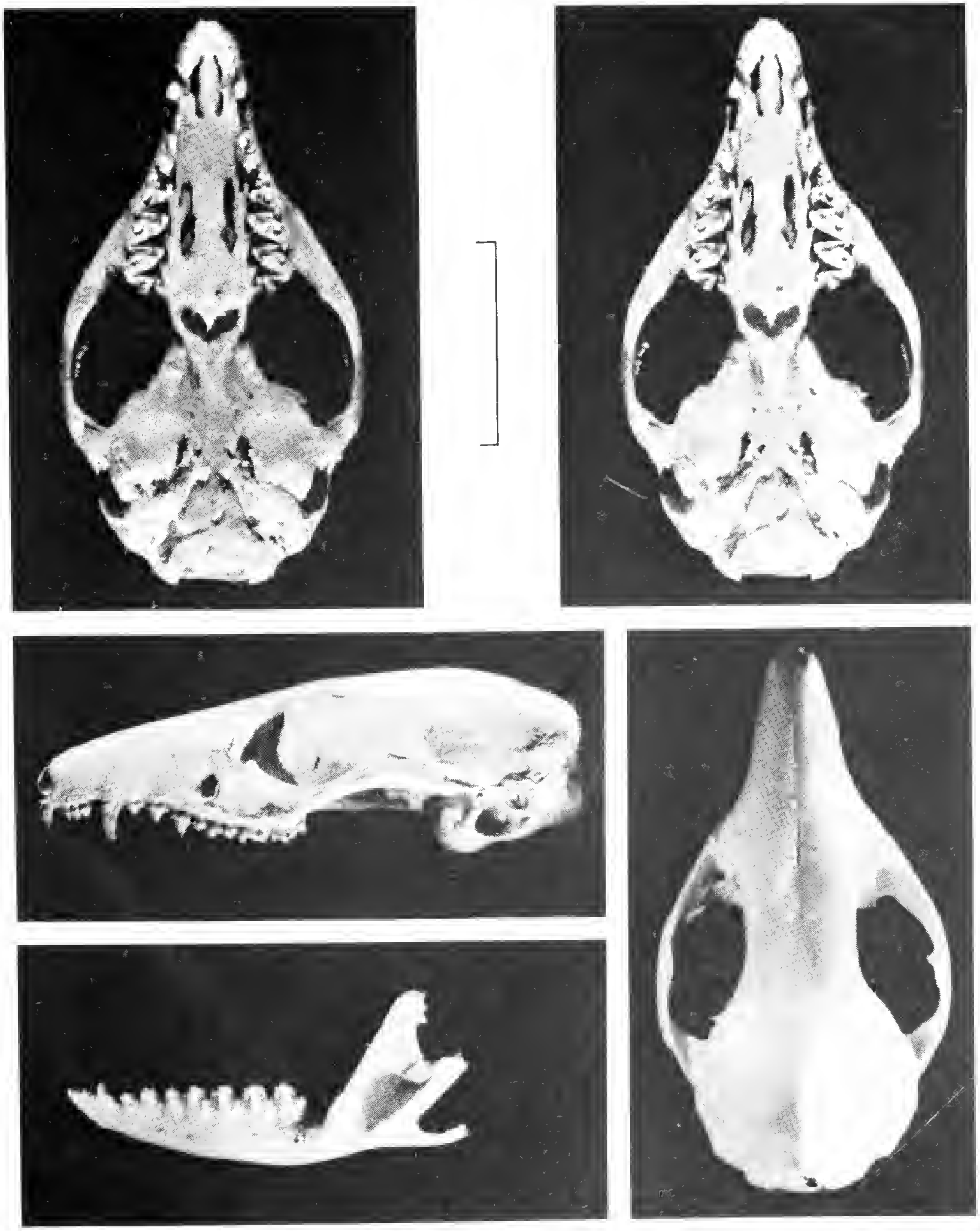

Figure 5 Skull and left dentary of the holotype of *S. dolichura*. The ventral aspects of the skull are stereopairs. Scale line, 10 mm.

Nipple Number

Eight nipples only (N = 19).

Dentition

As for *S. murina* except for the following points: $C^{\underline{1}}$ usually slight to moderately premolariform, occasionally caniniform; $C^{\underline{1}}$ short, frequently subequal and occasionally slightly taller crowned than $P^{\underline{4}}$. $dP^{\underline{4}}$ StD slightly shorter than its paracone (e.g. WAM M2007, WAM M20119). dP_4 has no metaconid on posterior flank of protoconid. StC and StE absent $M^{\underline{1}}$ to $M^{\underline{4}}$. M^3 metacristid shorter or subequal to its crown length. P_3 always taller crowned than $P_{\overline{1}}$ and $P_{\overline{4}}$; P_4 usually taller crowned than $P_{\overline{1}}$. Entoconids commonly absent but when present are tiny and restricted to M_2 and $M_{\overline{3}}$.

Skull and Dentary

As for *S. murina*.

Distribution and Habitat

Sminthopsis dolichura is widely distributed in the semi-arid savannah mallee country of Western Australia, and South Australia west of the Flinders Range (Figure 3).

It occurs in all major vegetation and landform types (Chapman and Kitchener [1978, 1981], Kitchener and Chapman, [1979], R.A. How [pers. comm.] and N. McKenzie [pers. comm.]) except samphire vegetation on salt flats and paleo drainage lines.

These vegetation formations range from:

- woodlands to open woodlands; these are usually dominated by *Eucalyptus* spp, but occasionally by *Acacia* spp. and *Casuarina* spp;
- tall to low and open to closed shrublands and heaths; these are usually dominated by a mixed assemblage of myrtaceous and proteaceous plants, but occasionally as a pure association of *Melaleuca* spp. (e.g. *M. uncinata*), or *Acacia* spp. *(A. resinomarginea, A. signata)* or*Casuarina* spp. *(C. campestris)*;
- spinifex *Triodia scariosa)* with mallee emergents.

The substrate of these formations comprise yellow, grey and red sands, and grey brown and red duplex soils involving clays and loams, occasionally the duplex soils have a pebble matrix.

The type locality of *S. dolichura* is a low woodlands of *Eucalyptus salubris* which is almost lacking in understory except for occasional low (< 1 m high) shrubs of *Cratystylis conocephala, Maireana sedifolia, Scaevola spinescens, Rhagodia spinescens* and *Atriplex vesicaria*. The soil A-horizon is a highly calcareous dark red loam with clay content increasing with depth (K. Newby, pers. comm.) (Figure 6).

Origin of Name

From the Greek: *dolchos* (long) and *ura* (tail).

Specimens Examined

Stuart Shelf group (SS)

Kootaberrra, 31°59′S, 137°30′E, 1♂, SAM M9624. Wirraminna, 31°21′S, 136°25′E, 1♂, SAM M7537 (S).

Adelaide Fold Belt group (AFB)

Weeroona Bay, 33°00′S, 137°46′E, 1♀, SAM M10999.

Figure 6 Type locality of *S. dolichura*. The pit-trap from which the holotype was collected is in the foreground (photo: R.A. How).

Gawler Block group (GB)
Blesing (SW Eyre Penin.) 34°00′S, 135°00′E, 1♂, SAM M7535 (S). Paney Stn, 32°34′S, 135°27′E, 1♂, SAM M10834, Ceduna-Tarcoola, 31°33′S, 133°58′E, 1♀, SAM M9268. Lakes Giles Cons. Pk, 32°58′S, 136°45′E, 1♂, SAM M10344. Middle Back Range, 33°10′S, 137°07′E, 1♂, SAM M10995. Hincks Nat. Pk, 33°55′S, 135°55′E, 1♀, SAM M9408. Lake Everard HS, 31°44′S, 135°10′E, 1♀, WAM M18977.

Arckaringa Basin group (AB)
5 km N Ooldea, 30°24′S, 131°50′E, 1♂, SAM M9353.

Albany-Fraser Province/Coolgardie group (AFC)
Buningonia Spring area, 31°28′10″S, 123°36′00″E, 1♂, WAM M17985 (holotype) Buningonia Spring area, 31°27′S, 123°32′E, 2♂, 1♀, WAM M17994, WAM M17995, WAM M17986.

Yilgarn Block/Darling group (YBD)
Gingin, 31°19′S, 115°45′E, 1♂, WAM M16811.

Perth Basin/Irwin group (PBI)
Eneabba, 29°45′S, 115°24′E, 1♂, WAM M18066.

Carnarvon Basin/Irwin group (CBI)
34 km NW Murchison Hse, HS 27°21′S, 114°09′E, 1♀, WAM M7153.

Yilgarn Block/Avon group (YBA)
Buntine Nat. Res., 30°00′S, 116°37′E, 1♀, WAM M10284. Nth Bungalla Nat. Res., 31°32′S, 117°35′E, 1♀, WAM M13705. 13 km W Bolgart, 31°17′S, 116°23′E, 1♀, WAM M7149. Boyagin Nat. Res., 32°28′S, 116°52′E, 1♀, WAM M18941. Durokoppin Nat. Res., 31°25′S, 117°45′E, 1♀, WAM M13905. Wilroy Nat. Res., 28°38′S, 115°38′E, 1♀, WAM M15420. 1 km S Walyahmoning Rock, 30°39′S, 118°45′E, 1♀, WAM M8738. Tallering HS, 28° 19′S, 115°51′E, 1♂, WAM M6386. Karroun Hill Nat. Res., 29°58′S, 117°43′E, 1♂, WAM 12608. E Yorkrakine Nat. Res., 31°24′S, 117°40′E, 1♂, WAM M13142. Nugadong Nat. Res., 30°14′S, 116°49′E, 1♂, WAM M13636. Sth Badjaling Nat. Res., 31°53′S, 117°53′S, 1♂, WAM M13704. Yorkrarkine Rock Nat Res., 31°27′S, 117°30′S, 1♂, WAM M13709. Jibberding, 29°53′S, 116°49′E, 1♂, WAM M24549.

Yilgarn Block/Austin group (YBU)
Yundamindra area, 29°16′S, 122°24′E, 2♂, WAM M22074, WAM M2007 (J). Goongarrie area, 29°55′S, 121°08′N, 2♂, WAM M17546, WAM M20039. Goongarrie area, 29°55′S, 121°09′E, 1♂, WAM M20047. Goongarrie area, 29°54′S, 121°10′E, 1♂, WAM M20050. Yuinmery area, 28°32′S, 119°12′E, 1♀, WAM M17817. 6 km W Pinyalling Hill, 29°06′S, 117°15′E, 1♀, WAM M6998. 24 km S Pindar, 28°26′S, 116°02′E, 1♀, WAM M19056. Mt Elvire area, 29°33′S, 119°36′E, 2♂, 1♀, WAM M18313, WAM M18309, WAM M18312, Mt Elvire area, 29°19′S, 119°36′E, 2♂, WAM M18306, WAM M18310. Mt Elvire area, 29°27′S, 119°36′E, 1♂, WAM M18352. Mt Elvire area, 29°32′S, 119°39′E, 1♂, WAM M18307.

Yilgarn Block/Coolgardie group (YBC)
18 km NW Norseman, 32°03′S, 121°41′E, 1♀, WAM M11335. Bungalbin Hill area, 30°19′S, 119°43′E, 2♀, WAM M17943, WAM M17952. Bungalbin Hill area, 30°18′S, 119°44′E, 1♂, 1♀, WAM M20293, WAM M17759. Bungalbin Hill area, 30°18′S, 119°43′E, 1♂, WAM M20310. Mt Manning area, 30°00′S, 119°36′E, 2♂, 1♀, WAM M18303, WAM M18305, WAM M18301. McDermid Rock area, 32°01′S, 120°45′E, 4♂, 1♀, WAM M17675, WAM M17686, WAM M20119 (J), WAM M20120, WAM M17677. Mt Jackson area 30°25′S, 119°25′E, 1♂, WAM M17742. Mt Jackson area, 30°25′S, 119°15′E, 2♂, WAM M20258, WAM M20273. Mt Jackson area, 30°15′S, 119°15′E, 1♂, WAM M20274. Kalgoorlie area, 30°33′S, 121°14′E, 4♂, 1♀, WAM M20441-5. Kurnalpi area, 30°41′S, 122°35′E, 2♂, 3♀, WAM M20436-40. Higginsville, 31°45′S, 121°42′E, 2♂, WAM M5442, WAM M5463. Woodline area, 31°50′S, 122°19′E, 1♂, WAM 17969. Karroun Hill Nat Res., 30°12′S, 118°31′E, 1♂, WAM M14725.

The Editorial Sub-Committee draws to your attention two printing errors in Kitchener, D.J., Stoddart, J. and Henry, J. *Rec. West. Aust. Mus.* 1984 11 (3): 201-248.
Enclosed are two adhesive emendation slips for insertion as follows:

on page 221, the heading '***Smithopsis gilberti*** **sp. nov.**' should be replaced by ***Sminthopsis gilberti*** **sp. nov.**

on page 230, the heading '***Smithopsis aitkeni*** **sp. nov.**' should be replaced by ***Sminthopsis aitkeni*** **sp. nov.**

Please would you personally attend to this matter so that your copy of the Records conforms with the official version.
It is essential that this emendment should be made to avoid nomenclatural confusion.

Smithopsis gilberti sp. nov.

(Figure 2e, 4b, 7, 8; Table 1)

Holotype

WAM M18718; adult male, skull and dentaries, carcase (liver removed for electrophoresis) in 70% ethyl alcohol. Pit-trapped by G. Harold on 10 July 1980, 10 km and 260° from Mt Saddleback, Western Australia, (32°58′15″S, 116°20′20″E) at 240 m above sea level. Type locality described under Distribution and Habitat.

Paratypes

Eight females and 10 males; see Specimens Examined.

Diagnosis

Sminthopsis gilberti differs from *S. murina* as follows (measurements are means, in millimetres): both longer feet (17.9 v. 16.7) and ears (21.1 v. 18.1); dorsal pelage a light fuliginous rather than a brownish colour; not more than eight teats; C^1-M^4 longer (10.2 v. 9.7); M^3 metacristid normally shorter than its crown length. Differs from *S. dolichura* as follows: shorter tail (80.2 v. 92.8) such that TV < HV; both longer pes (v. 16.7) and ears (v. 19.3); generally larger skull, particularly maximum length (27.1 v. 25.0) and maximum width (14.4 v. 13.1), longer DCI_1 (19.8 v. 17.9) and distance across LM^3-RM^3 (6.0 v. 5.5); lower CONRAM: M_1-M_4 ratio (0.72 v. 0.75). Differs from *S. griseoventer* as follows: both longer feet (17.9 v. 16.3) and ears (21.1 v. 17.7); whiter ventral pelage; dP^4 has three rather than two major cusps; C_1 taller crowned rather than shorter than or subequal to P_3; P_3 crown shorter than or subequal to, rather than longer than P_4; entoconids on M_2 and M_3 absent or very small rather than moderate or large; longer nasal length (10.3 v. 9.3); larger minimum orbital width (5.3 v. 5.0) shorter IPVAC (3.3 v. 4.0); lower CONRAM: M_1-M_4 ratio (0.72 v. 0.78). Differs from *S. aitkeni* as follows: lower maximum skull height (7.3 v. 7.7); shorter C^1-M^4 (10.2 v. 10.8); shorter IPVAC (3.3 v. 4.2); longer nasal length (10.3 v. 9.8); dorsal pelage a lighter fuliginous colour and ventral pelage whiter; shorter tail length (80.2 v. 96.0); longer ear (21.1 v. 18.2); C_1 crown taller rather than subequal to or shorter than P_3; entoconids on M_2 and M_3 absent or very small rather than moderate to relatively large. If the above diagnosis fails to identify a specimen it may be distinguished from *S. murina*, *S. dolichura*, *S. griseoventer* and *S. aitkeni* by the discriminant function analysis presented herein. Differs from other species of *Sminthopsis* in the same way that *S. murina* (*sensu* Archer, 1981) differs from them (see Archer [1981]).

Description

Pelage

Colour similar to *S. dolichura*.

Tail

Average tail to vent length 80.2, i.e. slightly less than average nose to vent length of 86.5. Tail invariably thin.

Hindfoot

As for *S. murina*, except no specimens with metatarsal or post hallucal granules.

Nipple Number

Eight nipples (N = 4).

Dentition

As for *S. murina* except for the following: crown height of I^2, I^3 and I^4 commonly subequal but I^2 frequently slightly shorter than I^3 and I^4 which are subequal. Crown width of I^2, I^3 and I^4 normally subequal but occasionally $I^2 < I^3 < I^4$. Posterolingual cingula infrequently enlarged on P^3. dP^4 stylar cusp D slightly shorter than its paracone (e.g. WAM M20091). dP_4 lingual cingulum absent. StC slight to moderate, infrequently present on M^1 to M^3. StE small to moderate, frequently present on M^1 to M^3. M^3 metacristid usually shorter but occasionaly subequal to its crown length. C_1 taller crown than P_3. P_4 crown taller or subequal to P_3 which is taller than P_2.

Skull and Dentary

As for *S. murina.*

Distribution and Habitat

Sminthopsis gilberti occurs in the near coastal ranges and parts of the wheatbelt of south-western Western Australia (Figure 3).

It appears to favour heathlands on generally 'heavy' soils, although it has also been captured in eucalypt woodlands and mallee, although these formations usually have a heath understrata.

In the Darling Range it occurs 593 m above sea level in myrtaceous heaths, dominated by *Macrozamia reidleyi, Calothamnus quadrifidus* and *Xanthorrhoea preissii,* on shallow granitic soils with high clay content, and strewn with small angular granitic rocks. As well it is found on lower slopes incorporating also the dominant proteaceous heath elements: *Dryandra carduacea, Petrophile* spp. and *Leptospermum* sp., on granitic soils which have a surface scree of laterite pebbles. The type locality is at the base of the ranges (240 m above sea level) in a small gully with a seasonal creek. This is vegetated with an open woodland of *Eucalyptus wandoo* and *E. calophylla* with occasional *E. marginata;* there is a sparse, 2 m high, shrub layer of *Xanthorrhoea preissii* and *Acacia extensa* and a mixed, < 1 m high, shrub layer on light-brown sandy loam with some pisolitic gravel. The vegetation at this type locality (Figure 8) was extensively burnt during the summer of 1976/1977.

In the central and southern Wheat Belt *S. gilberti* occurs in open shrub mallee of *Eucalyptus eremophila* and occasional *E. foecunda* over a moderately dense heath to 2 m height of *Melaleuca uncinata, M. spathulata* and *Hakea lissocarpha* over low sedges on sandy loam. Also it is in open heaths dominated by *Casuarina campestris* on gravelly and coarse sandy soils.

At the eastern edge of the southern Wheat Belt, at Lake Cronin, it occurs in open woodlands of Salmon Gum, *Eucalyptus salmonophloia,* over sparse shrubs including *Exocarpus* spp. and *Acacia* spp., on heavy red-brown loam. It is also in moderately dense, 5 m high, regenerating mallee on heavy red-brown loam.

Origin of Name

Named after John Gilbert who collected extensively in the south-west of Western Australia between 1843-44.

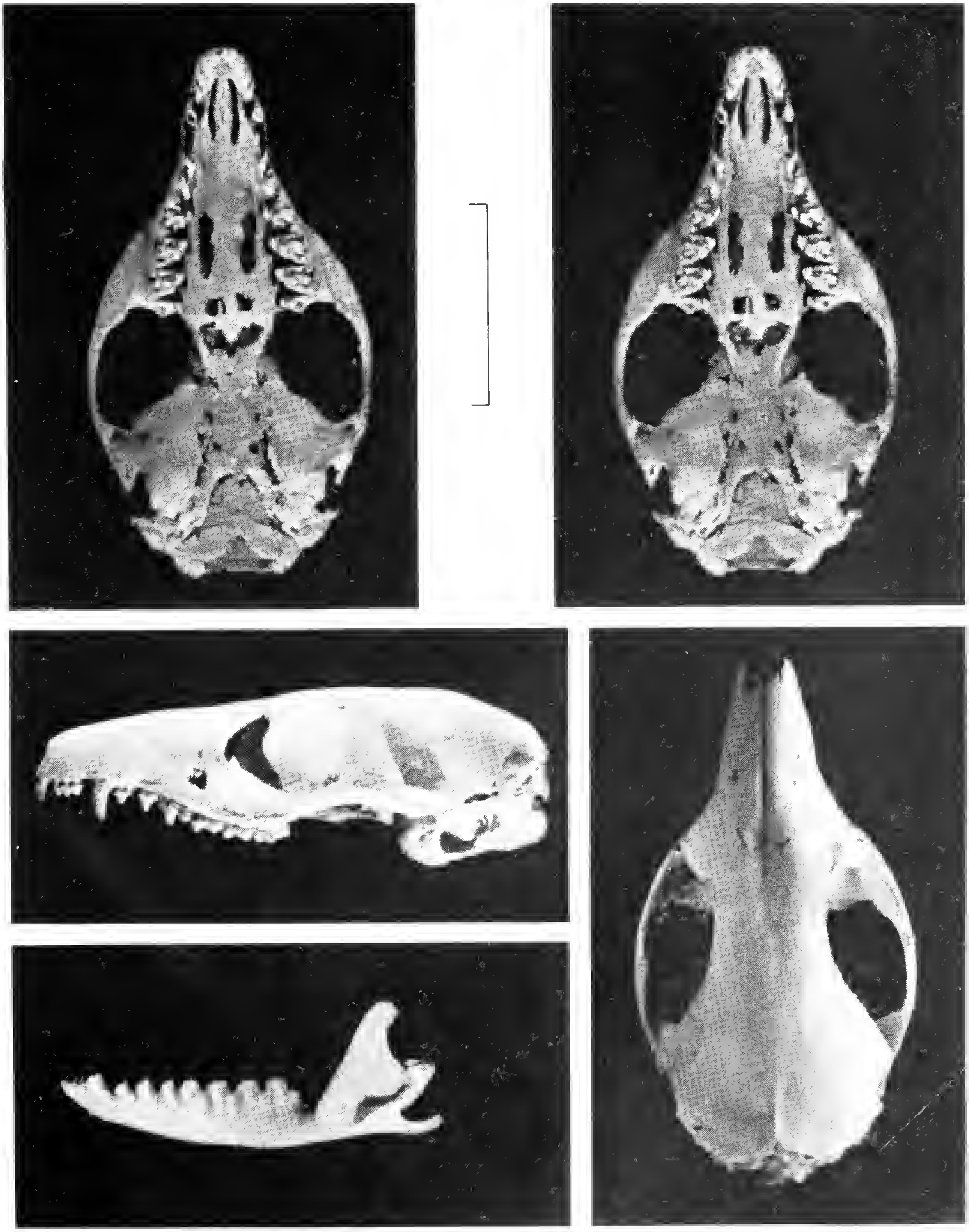

Figure 7 Skull and left dentary of the holotype of *S. gilberti*. The ventral aspect of the skull are stereopairs. Scale line, 10 mm.

Figure 8 Type locality of *S. gilberti* showing the dry watercourse in the foreground (photo: N.T. Allen).

Specimens Examined

Yilgarn Block/Darling group (YBD)

Mt Saddleback, 32°58′15″S, 116°20′20″E, 1♂. WAM M18718 (holotype). Gracefield, 34°05′S, 117°20′E, 1♀, WAM M16005. Kojonup, 33°50′S, 117°09′E, 1♀, WAM M16014 (K). Lowden, 33°32′S, 115°58′E, 1♂, WAM M1874 (S). Churchman Brook Dam, 32°09′S, 116°05′E, 1♂, WAM M6878.

Perth Basin/Darling group (PBD)

Nr Wonnerup Siding, 33°48′S, 115°27′E, 1♂, WAM M12474.

Yilgarn Block/Avon group (YBA)

Tambellup, 34°02′S, 117°38′E, 1♂, 2♀, WAM M662 (S), WAM M709 (S), WAM M740 (S). Woodlands, 33°59′S, 117°39′E, 1♀, WAM M852 (S). Nr Congelin, 32°47′S, 116°58′E, 1♀, WAM M19523. Narrogin, 32°56′S, 117°11′E, 1♂, WAM M1564 (S). Brookton 32°22′S, 117°00′E, 1♂, WAM M18454.

Yilgarn Block/Roe group (YBR)

Lake Cronin area, 32°23′S, 119°45′E, 1♀, WAM M17642. Lake Cronin area, 32°24′S, 119°45′E, 1♂, 1♀, WAM M20091 (J), WAM M17643. Nr Kebaringup, 34°05′S, 118°08′E, 1♂, WAM M4 (S). Nth Tarin Rock, 32°59′S, 118°14′E, 1♂, WAM M8222 (S). Dragon Rocks Res., 32°49′S, 119°02′E, 1♂, WAM M9938.

Sminthopsis griseoventer sp. nov.

(Figures 2d, 4c, 9, 10; Table 1)

Holotype

WAM M24543. Adult male, skull and dentaries, carcase (liver removed for electrophoresis) in 70% ethyl alcohol. Pit-trapped by J.N. Dunlop on 15 August 1982 13.2 km and 68° from Bindoon, Western Australia (31°18′15″S, 116°01′00″E) at approximately 150 m above sea level. Type locality described under Distribution and Habitat.

Paratypes

13 females and 21 males; see Specimens Examined.

Diagnosis

Sminthopsis griseoventer differs from *S. murina* as follows (measurements are mean, in millimetres): dorsal pelage light fuliginous rather than brownish color and ventral pelage greyish rather than white; not more than eight nipples; $C^{\underline{1}}$-$M^{\underline{4}}$ longer (10.2 v. 9.7); $dP^{\underline{4}}$ with only two major cusps (StD absent); $M^{\underline{3}}$ metacristid shorter than or subequal to its crown length; $C_{\overline{1}}$ crown height normally less than or subequal to rather than greater than that of $P_{\overline{3}}$; entoconids on $M_{\overline{2}}$ and $M_{\overline{3}}$ medium to large rather than absent or small; generally longer IPVAC (4.0 v. 3.3); and higher CONRAM: $M_{\overline{1}}$-$M_{\overline{4}}$ ratio (0.78 v. 0.74). Differs from *S. dolichura* as follows: shorter tail (82.2 v. 92.8); grey rather than white ventral pelage; larger skull particularly maximum length (26.4 v. 25.0) and maximum width (14.1 v. 13.1); longer $C^{\underline{1}}$-$M^{\underline{4}}$ (10.2 v. 9.3); $dP^{\underline{4}}$ with only two major cusps (StD absent); $C_{\overline{1}}$ crown height usually lower rather than taller than that of $P_{\overline{3}}$; entoconids on $M_{\overline{2}}$ and $M_{\overline{3}}$ moderate to relatively large rather than absent or small; IPVAC frequently longer (4.0 v. 3.0). Differs from *S. gilberti* as follows: both shorter feet (16.3 v. 17.9) and ears (17.7 v. 21.1); grey, rather than white ventral pelage; $dP^{\underline{4}}$ with only two major cusps (StD absent); $C_{\overline{1}}$ subequal or shorter, rather than taller crowned than $P_{\overline{3}}$; $P_{\overline{3}}$ taller rather than shorter crowned than $P_{\overline{4}}$; entoconids on $M_{\overline{2}}$ and $M_{\overline{3}}$ moderate to large rather than absent or very small; shorter nasal length (9.3 v. 10.3); smaller minimum orbital width (5.0 v. 5.3); longer IPVAC (4.0 v. 3.3); higher CONRAM: $M_{\overline{1}}$-$M_{\overline{4}}$ ratio (0.78 v. 0.72). Differs from *S. aitkeni* as follows: shorter tail (82.2 v. 96.0) such that TV normally less than HV; shorter hind feet (16.3 v. 17.5); dorsal pelage light rather than a dark fuliginous colour; ventral pelage 'grizzled' grey rather than light grey; smaller maximum skull height (7.4 v. 7.7); shorter $C^{\underline{1}}$-$M^{\underline{4}}$ (10.2 v. 10.8); $M^{\underline{1}}$-$M^{\underline{4}}$ (5.4 v. 5.7) and $M^{\underline{1}}$-$M^{\underline{3}}$ (4.8 v. 5.0); shorter $I_{\overline{1}}$-$M_{\overline{4}}$ (11.6 v. 12.3); smaller minimum orbital width (5.0 v. 5.4); smaller nasal length (9.3 v. 9.8) and higher CONRAM: $M_{\overline{1}}$-$M_{\overline{4}}$ ratio (0.78 v. 0.71). If the above diagnosis fails to identify a specimen then it may be distinguished from *S. murina*, *S. dolichura*, *S. gilberti* and *S. aitkeni* by the discriminant function analysis presented herein. Differs from other species of *Sminthopsis* in the same way that *S. murina* (*sensu* Archer, 1981) differs from them (see Archer [1981]).

Description

Pelage

Dorsal fur, including that on forearms and feet, and sides of body, Fuscous Black at base, tipped with mixture of Light Greyish Olive and Chaetura Drab; the latter predominates providing a light fuliginous colour lower on the back. Apart from incomplete ring (broken posteriorly) of Chaetura Drab around eye, face and cheeks Light Greyish Olive. Hair of

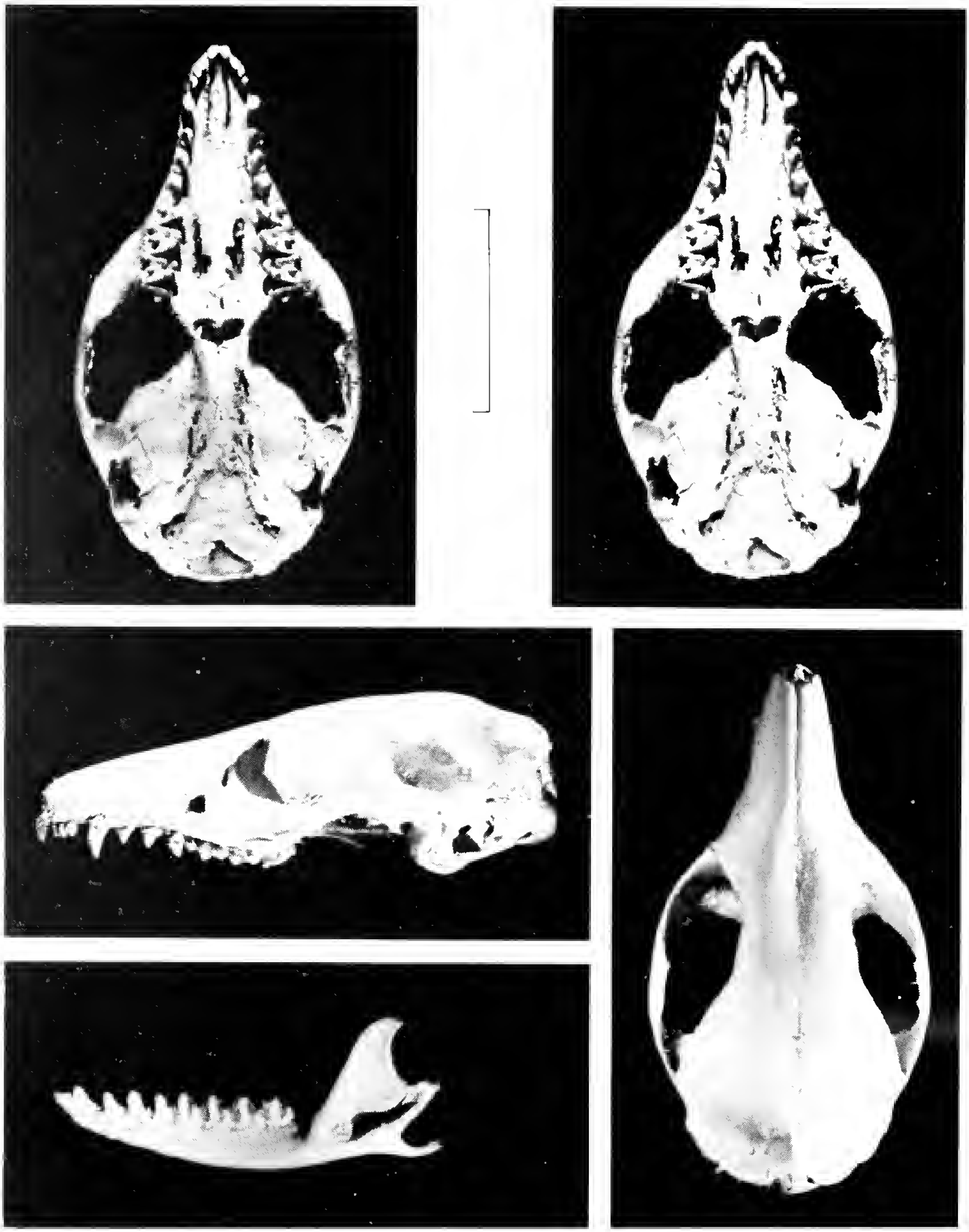

Figure 9 Skull and left dentary of the holotype of *S. griseoventer*. The ventral aspect of the skull are stereopairs. Scale line, 10mm.

ventral surface including fore and hind feet, Dark Greyish Olive base for four-fifths or more of its length, tipped with Light Gull Grey – producing a grizzled grey colour overall. Pes and manus white. Dorsal and ventral surfaces of tail the colour of their respective body pelage surfaces.

Tail

Average tail to vent length 82.2; i.e. approximately equal to the average nose to vent length of 83.7. Tail invariably thin.

Hindfoot

As for *S. murina* except apical granule of fourth interdigital pad subequal to that of other pads, and rarely fused with proximal granule. Small metatarsal granules infrequently present and usually associated with post hallucal granules (WAM M14584, WAM M24325, WAM M18296). The latter granules usually small but occasionally several fuse to form an elongate post hallucal pad.

Nipple Number

Eight (N = 7) or six (N = 2) nipples.

Dentition

As for *S. murina* except for the following: dP^4 has three roots and two main cusps – a paracone and a taller metacone; protocone low and rudimentary; StD absent; small but obvious anterobuccal cusp may represent StA, metacristid very slight (e.g. WAM M18854, WAM M11074). dP_4 has no suggestion of metaconid on posterior flank of protoconid. StC tiny, occasionally present but on M^3 only. StE tiny to small, occasionally present but on M^3 only. M^3 metacristid shorter or subequal to its crown length. C_1 crown height normally less than or subequal to that of P_3 but occasionally slightly larger. P_3 taller crowned than P_1 and P_4; relative height of P_1 and P_4 variable. Buccal and lingual cusps absent or very narrow on P_1, P_3 P_4 and C_1. Parastylids present on M_3 and M_4, rarely on M_2, absent M_1. Moderate to large entoconids normally present on M_2 and M_3, small to moderate entoconids variable present on M_1, rarely on M_4.

Skull and Dentary

As for *S. murina* except for the following: rostral depression of frontals shallow, frequently absent. IPVAC tends to be longer: premaxillary vacuity normally extends posteriorly to a point in line with anterior edge of P^1 but frequently, also to a point in line with cusp of P^1; maxillary vacuity normally extends anteriorly to a point approximately in line with protocone of M^1, but frequently also with anterior edge of M^1.

Distribution and Habitat

Sminthopsis griseoventer is restricted to the coastal plain and adjacent lateritic ranges of south-west Western Australia (Figure 3).

It occurs in a wide range of habitats including the major vegetation formations and soil types in the region:

- open eucalypt woodlands, 200 m above sea level; these are dominated by Jarrah, *E. marginata*, with occasional *E. calophylla*. The understorey is a very open low woodland of *Banksia grandis* and *Persoonia longifolia* over a low mixed shrub assemblage on laterite gravel with a high clay content;

Figure 10 Type of locality of *S. griseoventer* (photo: N. Dunlop).

- moderate dense Jarrah woodlands over dense shrubland of *Melaleuca* spp., *Agonis parviceps* and *Euanora aristata* on grey sand;
- moderately dense low woodland of *Banksia attenuata* and *B. menziesii* over *Adenanthos cygnorum* on deep whitish silicous soil;
- seasonal swampland vegetated with '*Melalenca* and rushes';
- Eucalypt mallee over *Xanthorrhoea* sp. on stony substrate;
- '*Banksia coccinea* scrub';
- *Banksia speciosa* shrubland 3 m high, over mixed heath 0.5 m high, on yellow gravelly sand;
- dense heath on lateritic breakaway country.

The type locality of *S. griseoventer* is described by N. Dunlop (pers. comm.) as follows: '*Banksia attenuata, B. menziesii* and *Eucalyptus todtiana* open low woodland B over *Casuarina humilis* and *Hakea* sp. low scrub A over mixed low heath C dominated by *Melaleuca scabra* on deep, whitish-yellow sand. Stand not burnt for 12-15 years. Other plant species in low heath include *Hibbertia* spp., *Petrophile linearis, Calothamnus quadrifidus, Gompholobium, Synaphea, Daviesia, Eremeae* and *Xanthorrhoea* spp.' (Figure 10).

Origin of Name'

From the Latin – *griseus* (grey) and *venter* (abdomen).

Specimens Examined

Albany-Fraser Province/Roe group (AFR)

Nr Ravensthorpe, 33°35'S, 119°35'E, 1♂, WAM M10927.

Albany-Fraser Province/Eyre group (AFE)

Fitzgerald River Nat. Pk, 34°16'S, 119°25'E, 3♀, WAM M15170, WAM M15457, WAM M24325. Mt Bland, 34°11'S, 119°28'E, 1♀, WAM M8075. Nr Pt Dempster, 33°37'S, 123°49'E, 1♂, WAM M8652. Cape LeGrand Nat. Pk, 33°56'S, 122°09'E, 1♂, WAM M14584.

Albany-Fraser Province/Darling group (AFD)

Nr Walpole, 34°58'S, 116°32'E, 2♀, WAM M19039, WAM M19033. Nr Denmark, 34°53'S, 117°22'E. 1♀, WAM M3393. Denmark 34°58'S, 117°21'E, 2♂, WAM M1006 (S) WAM M1231 (S). King Creek, 34°51'S, 118°10'E, 1♀, WAM M7100 (K). Elleker, 35°00'S, 117°30'E, 1♀, WAM M1224 (S). Hay River, 34°48'S, 117°30'E, 1♀, WAM M1969 (S). Mt Manypeaks, 34°49'S, 118°16'E, 1♂, WAM M18296. Nr Torbay, 35°03'S, 117°32'E, 2♂, WAM M1841 (S), WAM M1126 (S). Chorkerup Siding, 34°50'S, 117°41'E, 3♂, WAM M1317 (S), WAM M1758 (S), WAM M1714 (S).

Yilgarn Block/Darling group (YBD)

68°, 13.2 km Gingin, 31°18'15"S, 116°01'00"E, 1♂, WAM M24543 (S) (holotype). Nr Gingin, 31°18'S, 116°01'E, 2♂, 1♀, WAM M24534-5, WAM M18854 (J). Worsley, 33°19'S, 116°00'E, 1♀, WAM M24555. Bridgetown, 33°50'S, 116°00'E, 1♂, WAM M8037.

Leeuwin Block/Darling group (LBD)

Forest Grove, 34°04'S, 115°06'E, 2♂, WAM M1642 (S), WAM M2059 (S). Augusta, 34°19'S, 115°09'E, 1♂, WAM M11074 (J).

Perth Basin/Darling group (PBD)

Newlands, 33°41'S, 115°53'E, 2♂, WAM M901 (S) WAM M1313 (S). Nr Mt Peron, 30°07'S, 115°09'E, 1♂, WAM M15987.

Perth Basin/Irwin group (PBI)

Badgingarra Nat. Pk, 30°30'S, 115°28'E.

Yilgarn Block/Roe group (YBR)

Nr Borden, 34°24'S, 118°05'E, 1♂, WAM M15196.

Smithopsis aitkeni sp. nov.

(Figure 2e, 11; Table 1)

Holotype

SAM M7664. Adult male, skull and dentaries, carcase in 70% ethyl alcohol, collected by P. Tiggerman on 29 April 1969 from 'Section 146 Hundreds of Cassini, Kangaroo Island South Australia' (35°35'S, 137°19'E).

Paratypes

Two females and 2 males; see Specimens Examined.

Diagnosis

Sminthopsis aitkeni differs from *S. murina* as follows (measurements are means, in millimetres): dorsal pelage dark fuliginous rather than a brownish colour; ventral pelage light grey rather than white; generally longer tail (96.0 v. 77.7); larger maximum skull height 7.7 v. 7.1); longer C^1-M^4 (10.8 v. 9.7); M^3 metacristid normally shorter than or subequal to rather than longer than its crown length; C_1 crown height shorter or subequal to rather than taller than that of P_3; entoconids on M_2 and M_3 medium to large rather than small to absent; and a generally longer IPVAC (4.2 v. 3.3). Differs from *S. dolichura* as follows: dorsal pelage darker fuliginous colour and ventral pelage light grey rather than white; larger skull, particularly maximum length (27.3 v. 25.0); maximum width (14.1 v. 13.1) and maximum height (7.7 v. 6.8); longer in all tooth dimensions particularly C^1-M^4 (10.8 v. 9.3). C_1 crown height subequal to or shorter than rather than longer than that of P_3; entoconids on M_2 and M_3 moderate or large rather than absent or very small; lower CONRAM: M_1-M_4 ratio (0.71 v. 0.75). Differs from *S. gilberti* as follows: dorsal pelage darker fuliginous colour and ventral pelage light grey rather than white; longer tail length (96.0 v. 80.2); shorter ear (18.2 v. 21.1); shorter nasal length (9.8 v. 10.3); longer IPVAC (4.2 v. 3.3); longer C^1-M^4 (10.8 v. 10.2); larger maximum skull height (7.7 v. 7.3); C_1 crown height subequal to or shorter rather than taller than that of P_4; entoconids on M_2 and M_3 moderate or large rather than absent or very small. Differs from *S. griseoventer* as follows: longer tail (96.0 v. 82.2), such that TV normally longer than HV; longer hind feet (17.5 v. 16.3) dorsal pelage dark rather than a light fuliginous colour: ventral pelage light grey rather than 'grizzled' grey: larger maximum skull height (7.7 v.7.4; longer C^1-M^4 (10.8 v. 10.2), M^1-M^4 (5.7 v. 5.4) and M^1-M^3 (5.0 v. 4.8); longer I_1-M_4 (12.3 v. 11.6); larger minimum orbital width (5.4 v. 5.0); larger nasal length (9.8 v. 9.3); shorter CONRAM: M_1-M_4 (0.71 v. 0.78). If the above diagnosis fails to identify a specimen then it may be distinguised from *S. murina*, *S. dolichura*, *S. gilberti* and *S. griseoventer* by the discriminant function analysis presented herein. Differs from other species of *Sminthopsis* in the same way that *S. murina* (*sensu* Archer, 1981) differs from them (see Archer [1981]).

Description

Pelage

Dorsal fur, including that on forearms and hind feet, and lateral body fur, Fuscous Black at base tipped with a mixture of Greyish Olive and Black; the latter predominate, particularly mesially, producing a dark fuliginous colour which extends anteriorly to forehead. Apart from patches of black around eye, face, cheeks and throat Light Gull Grey. Ventral fur

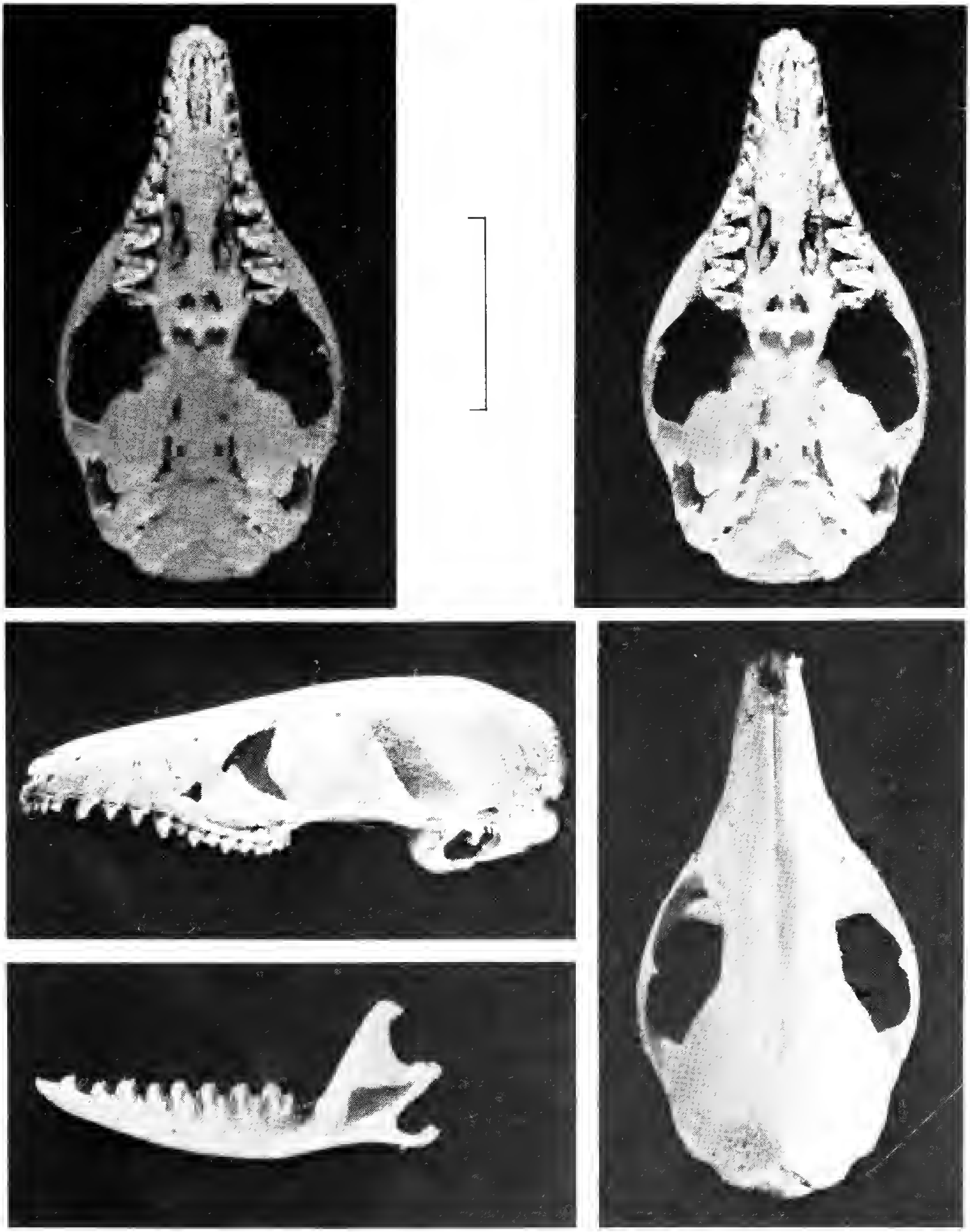

Figure 11 Skull and left dentary of the holotype of *S. aitkeni*. The ventral aspect of the skull are stereopairs. Scale line, 10 mm.

apart from chin, manus and pes, which are white, Deep Neutral Grey base for three-quarters of its length, tipped with white to Pale Gull Gray; overall this produces a light grey colour. Dorsal and ventral surfaces of tail the colour of respective body pelage surfaces.

Tail

Average tail to vent length 96.0, i.e. 10.5% longer than average nose to vent length of 86.9. Tail slightly incrassated in SAM M7664.

Hindfoot

As for *S. murina,* although apical granules of interdigital pads are a similar size; no obvious fusion of apical and proximal granules on fourth interdigital pad. No metatarsal or post hallucal granules.

Nipple Number

Six and probably two other nipples on damaged skin of SAM M8998.

Dentition

As for *S. murina* except for the following: crown width of $I^2 < I^3 < I^4$ or I^2, I^3 and I^4 subequal. No posterolingual enlargement of P^3 cingulum. Buccal and lingual cingula very slight to absent on P^1, P^3 and P^4. StC moderate on M^2 and M^3 of one specimen only. StE very small on M^3 of one specimen only. M^3 metacrista less than or equal to its crown length. C_1 crown height subequal to or shorter than that of P_3. Entoconids moderate to large on M_1 to M_3, small and variable present on M_4.
Note: No juveniles available for description of deciduous premolars.

Skull and Dentary

As for *S. murina* except for the following: distance between premaxillary and maxillary vacuities tends to be larger; premaxillary vacuity extends posteriorly to a point in line with anterior edge or anterior root of P^1; maxillary vacuity extends to a point in line with protocone or anterior edge of M^1

Distribution and Habitat

Known only from Kangaroo Island, South Australia. The holotype and SAM M7936 were collected from the base of a Blackboy, *Xanthorrhoea tateana* in sclerophyll mallee (Aitken 1972).

Origin of Name

Named after the late Peter Aitken, Curator of Mammals, South Australian Museum.

Specimens Examined

Kanmantoo Fold Belt group (KFB)

Kingscote (K.I.) 35°39'S, 137°38'E, 1♀, SAM M10196 (S). Cassini (K.I.) 35°35'S, 137°19'E, 2♂, SAM M7664 (holotype), SAM M7926 (S). Kangaroo I. 35°35'S, 137°16'E, 1♂, 1♀, SAM M8997 (S), SAM M8998 (S).

Unique Specimen

Archer (1981:98) refers to WAM M7495 (actually M7945) as a unique specimen. This was collected by P. Bridge in 1967 from the doline of Easter Cave near Augusta, Western Australia. The carcase was decomposing but its standard external body measurements were recorded by J.L. Bannister. Unfortunately this adult specimen could not be sexed. This presents difficulty in placing it against the species clustered by discriminant function analysis in Figure 12. If it is a female, then it does not cluster with any of the species distinguished in this study. If it is a male it clusters well with *S. dolichura.* WAM M7945 has no entoconids on M$_{\bar{1}}$-M$_{\bar{4}}$, as is the case in *S. dolichura.* However, it differs from *S. dolichura* in that its tail length is less than its nose to vent length (90.9 v. 93.7 mm). Also its CONRAM: M$_{\bar{1}}$-M$_{\bar{4}}$ ratio is higher than that of *S. dolichura* (0.80). If it is *S. dolichura,* which is not certain on the above evidence, then it is the only south-western coastal record of that species. A more likely explanation is that it is representative of an undescribed taxon – perhaps *S. fuliginosa* (Gould, 1852 – see later Nomenclatural Note).

Morphometric Analyses: Results and Discussion

The species show considerable difference in means and standard deviations for almost all variables (Table 1). While the majority of variables are strongly sexually dimorphic, the extent of this dimorphism is not significantly different between species (Table 2). Subsequent analyses separate data from the two sexes.

A previous study on dasyurids has suggested that skull variables can be coalesced into a few major factors (Kitchener *et al.* 1983). The potential for simplification of the current data set was assessed through principal component analysis.

Principal Component Analysis

Nearly all variables within the data set are highly intercorrelated. The 28 variables of the male data set are resolved into three major factors, with 24 of these variables having their highest loading on Factor I (Table 3). Factor I accounted for 54% of the total variation and almost certainly represented a measure of overall size. Neither Factor II nor Factor III reflect any obvious size or shape descriptions. Analysis of females produces an essentially similar solution (Table 3).

Discriminant Analysis

Discriminant analysis was used to select those combinations of morphological characters which best discriminate between the species of *Sminthopsis* examined here. For males, an analysis of skull, dentary and external body characters (weight and tragus not included as they are absent from many individuals), produces four functions (Table 4a) which assign indivuals to species with varying degrees of accuracy. Applying all four functions to individuals with complete data sets, *S. dolichura* (N = 50), *S. gilberti* (N = 10) and *S. aitkeni* (N = 2) are classified with complete accuracy. Of the *S. murina* (N = 25), two are incorrectly classified: WAM M6753 as *S. gilberti* and J1742 as *S. dolichura.* Two *S. griseoventer* (N = 19) are also incorrectly classified: WAM M901 as *S. murina* and WAM M1758 as *S. aitkeni.* Function I, which is greatly influenced by overall skull and dentary dimensions (BASCRANL, MSKW, DCI$_{\bar{1}}$) and tail length, primarily distinguishes *S. dolichura* from the other species. Function II, which is largely based on C^1-M^4 and hind foot length (HF), distinguishes *S. griseoventer* and *S. aitkeni.* Function III, which is largely dependent on overall skull dimensions (BASCRANL, MSKW) and M$_1$-$_3$ distinguishes *S. murina* from the other species and *S. griseoventer* from *S. aitkeni.* Function IV, which is influenced by characters describing the shape of the skull (MSKH, MINORB), overall size of dentary (DCI$_{\bar{1}}$), shape of the dentary (CONRAM) and tail length (TV), distinguishes maximally *S. griseoventer* and *S. aitkeni. S. gilberti* plots closest to *S. murina* on Functions I and II and is maximally distinguished from that species on Function III (Figure 12a).

Table 2 Analysis of variance for the skull and body characters of *Sminthopsis murina, S. gilberti, S. griseoventer, S. dolichura* and *S. aitkeni* grouped by OTU and sex. For key to variables see p. 202. P-values of 0.001 denote 0.001 or less.

Variable	OTU		Sex		Interaction	
	F-ratio	P	F-ratio	P	F-ratio	P
MAXL	26.71	0.001	41.59	0.001	1.71	0.151
BASCRANL	17.28	0.001	42.13	0.001	1.76	0.140
MSKH	45.66	0.001	39.16	0.001	1.39	0.240
MSKW	18.37	0.001	30.03	0.001	1.50	0.205
ZYHT	9.95	0.001	1.443	0.231	0.65	0.627
BUL	12.98	0.001	30.55	0.001	0.96	0.434
OBUL	12.52	0.001	20.78	0.001	0.12	0.975
INBUL	21.75	0.001	1.50	0.223	0.99	0.410
C^1-M^4	41.13	0.001	24.68	0.001	0.62	0.651
M^1-M^4	21.84	0.001	0.62	0.431	0.68	0.608
M^1-M^3	35.79	0.001	0.00	0.951	1.40	0.235
LM^3-RM^3	23.79	0.001	2.07	0.152	1.09	0.363
INORB	15.93	0.001	33.63	0.001	1.03	0.394
IPVAC	40.33	0.001	12.33	0.001	2.07	0.087
NASL	19.25	0.001	36.06	0.001	1.21	0.310
CRANW	22.12	0.001	22.57	0.001	0.98	0.420
DCI_1	25.74	0.001	47.64	0.001	1.19	0.317
I_1-M_4	62.52	0.001	31.19	0.001	1.16	0.332
M_1-M_4	46.39	0.001	0.42	0.519	0.73	0.572
M_1-M_3	48.73	0.001	0.26	0.614	0.80	0.529
ANGCON	1.88	0.124	2.16	0.147	0.60	0.615
CONRAM	2.21	0.078	15.05	0.001	1.96	0.128
WT	11.89	0.001	2.78	0.100	3.41	0.022
NV	7.05	0.001	0.31	0.582	1.76	0.163
TV	16.12	0.001	5.11	0.027	1.10	0.356
HF	10.17	0.001	13.44	0.001	2.51	0.062
EAR	9.92	0.001	6.14	0.015	0.46	0.710
TRAG	0.50	0.738	0.01	0.936	0.21	0.888

Comparable analysis for females (Table 4b) shows that they can be separated by the first two functions (Figure 12b). *S. gilberti* (N = 8), *S. griseoventer* (N = 8), *S. murina* (N = 15) and *S. aitkeni* (N = 2) are classified with complete accuracy. Of the *S. dolichura* (N = 26) one, SAM M9408 from Eyre Peninsula, is classified as *S. aitkeni.* Function I which is largely based on a range of characters related to skull shape, both tooth row length (C^1-M^4, M_1-M_3), shape of the dentary (DCI_1, CONRAM) and external body measurements (HV, TV and EAR) distinguishes *S. gilberti* and *S. dolichura* from each other and from the other species. Function II which is largely based on tooth row length (C^1-M^4) and dentary length DCI_1) distinguishes all species from each other except *S. dolichura* and *S. murina*.

Table 3 Factor loading for variables in the oblique factor analysis for the five species of *Sminthopsis*: only loadings greater than 0.3 are shown for males (in brackets) and females.

		Factor No.	
Variable	I	II	III
MAXL	.97 (.95)		
BASCRANL	.95 (.92)		
MSKH	.79 (.86)		
MSKW	.91 (.89)		(−.36)
ZYHT	.68 (.61)		(−.41)
BUL		−.62 (.76)	.46
OBUL	.88 (.82)		
INBUL	.68 (.82)		−.35
C^1-M^4	.89 (.92)	−.35	
M^1-M^4	.59 (.71)	−.63 (−.37)	.35 (.50)
M^1-M^3	.58 (.71)	−.68 (−.41)	.32 (.45)
LM^3-RM^3	.86 (.84)		
INORB	.55 (.68)	(.31)	
IPVAC	.50 (.68)		(−.33)
NASLEN	.79 (.73)		
CRANW	.82 (.78)		
DC-I_1	.94 (.96)		
I_1-M_4	.88 (.91)	−.31	
M_1-M_4	.64 (.78)	−.61 (−.41)	(.38)
M_1-M_3	.72 (.76)	−.54 (−.37)	(.41)
ANGCON	.72 (.72)	−.51	
CONRAM	.73 (7.4)		
WT	.71 (.80)	.33	−.49
NV	.58 (.73)	.35	
TV		.59 (.53)	.40 (.53)
HF	(.47)	(.36)	.68 (.32)
EAR		.57 (.61)	.34 (.45)
TRAG		.41 (.59)	
Percentage of variation explained	49.2 (54.0)	13.7 (10.4)	6.8 (7.4)

Table 4 Standardised discriminant functions for the variables selected by the discriminant analysis from the five species of *Sminthopsis (murina, dolichura, gilberti, griseoventer* and *aitkeni)* for (a) male skull, dentary and external body characters and (b) comparable female characters. Selection was based on minimisation of Wilk's Lambda (Klecka 1975) and variables are in descending order of discriminatory power based on this statistic.

Discriminant function scores are calculated as the summation of the products of the unstandardised discriminant function coefficients (in brackets) and the respective constant.

(4a)

Character	Discriminant Function I	II	III	IV
BASCRANL	0.885 (0.85)	−0.567 (−0.54)	1.331 (1.27)	0.326 (0.31)
MSKH	0.509 (−2.07)	0.301 (1.22)	−0.154 (−0.63)	1.230 (5.00)
MSKW	0.820 (1.00)	−0.268 (−0.33)	−1.180 (1.44)	0.338 (0.41)
BUL	0.312 (1.63)	0.040 (−0.21)	−0.301 (−1.57)	0.343 (1.79)
C^1-M^1	0.298 (−0.86)	1.124 (3.24)	−0.580 (−1.68)	−0.608 (−1.75)
LM^3-RM^3	0.537 (−1.42)	−0.393 (−1.04)	0.779 (2.06)	0.663 (1.75)
INORB	0.286 (1.09)	0.087 (0.33)	0.355 (−1.35)	0.856 (−3.25)
IPVAC	0.700 (1.96)	0.316 (0.88)	0.239 (0.67)	0.398 (1.11)
NASLEN	0.264 (0.39)	0.310 (−0.46)	0.010 (0.01)	0.462 (0.68)
DC-I_1	1.763 (2.11)	−0.648 (−0.78)	−0.197 (−0.24)	−1.200 (−1.44)
M_1-M_4	0.483 (2.83)	0.571 (3.34)	0.280 (1.64)	0.085 (0.50)
M_1-M_3	0.408 (2.70)	0.427 (2.83)	0.995 (−6.58)	0.245 (1.62)
ANGCON	0.231 (0.84)	0.526 (1.93)	0.508 (1.86)	0.298 (1.09)
CONRAM	0.041 (0.12)	0.750 (2.22)	0.351 (1.04)	1.128 (−3.34)
TV	1.148 (0.15)	0.583 (0.08)	0.234 (−0.03)	0.830 (0.11)
HF	0.270 (0.34)	0.887 (−1.11)	−0.080 (0.10)	0.230 (0.29)
EAR	0.160 (0.13)	0.293 (−0.23)	−0.334 (−0.26)	0.298 (0.24)
CONSTANT	24.04	8.07	24.43	20.64

(4b)

Character	Discriminant Function I	II	III
MSKH	0.470 (1.82)	0.584 (2.27)	0.205 (0.79)
ZYHT	0.936 (5.77)	0.073 (0.45)	0.212 (1.31)
BUL	0.393 (−2.14)	0.169 (0.92)	0.056 (−0.30)
INBUL	0.326 (1.40)	0.445 (1.90)	0.094 (0.40)
C^1-M^1	0.833 (2.49)	1.412 (4.21)	0.792 (2.36)
M^1-M^3	0.478 (2.97)	−0.740 (−4.60)	−0.038 (−0.24)

(4b) continued

Character	Discriminant Function I	 II	 III
LM^3-RM^3	−0.638 (−1.63)	−0.092 (−0.23)	1.023 (2.61)
INORB	−0.655 (−2.48)	−0.303 (−1.15)	−0.960 (−3.64)
IPVAC	0.203 (0.43)	0.264 (0.56)	0.267 (0.57)
NASLEN	−0.646 (−1.31)	0.005 (0.01)	−0.164 (−0.33)
DC-I_1	−1.887 (−2.31)	−1.819 (−2.23)	0.520 (0.64)
M_1-M_3	−1.015 (−7.13)	0.224 (1.57)	−0.155 (−1.09)
CONRAM	1.222 (3.66)	0.642 (1.92)	0.028 (0.08)
NV	0.946 (0.12)	0.286 (0.04)	−0.435 (−0.06)
TV	2.191 (0.34)	0.444 (0.07)	−0.411 (−0.06)
HF	−0.343 (−0.36)	−0.252 (−0.27)	−0.484 (−0.51)
EAR	−1.107 (−0.64)	−0.605 (−0.35)	−0.125 (−0.07)
CONSTANT	71.96	−11.21	26.98

Phenetic and Phylogenetic Analysis

The generalised patterns of most classifications whether male, female, phenetic or phylogenetic are essentially similar but minor details vary (Figures 13, 14). Similarities are (a) groupings of *S. dolichura* OTUs usually with a monophyletic origin, (b) groupings of most *S. gilberti* OTUs, (c) splitting of *S. murina* into two groups, one always containing the NEF and LFB OTUs with the other always containing the HFB OTU and arising close to *S. aitkeni* and (d) widely dispersed placement of *S. griseoventer* OTUs often intergrading with *S. murina*.

The most important differences between the Wagner trees arise from the shifting placement of MB, OB and CMB OTUs between the two *S. murina* groups and the disparity of the direction of the Wagner trees for the male and female groups. In addition to the latter, Wagner trees for males and females are highly discordant, whether these trees are produced from the raw (Figure 14), gap-coded or 'size free' data. Groupings on both of the latter two are similar to those of the former.

Wagner trees are rooted using a population of *Ningaui ridei* as an outgroup, but the direction and branching patterns of these trees are concordant with those rooted with *Sminthopsis granulipes* and *S. crassicaudata* and *S. macroura* or those rooted through the branch connecting the two most divergent OTUs without outgroups. Neither did the inclusion of the tragus measurements, causing a decrease in the number of populations (as not all had tragus data), cause any alteration in the Wagner trees. Thus although patterns differ, individual Wagner trees are quite robust.

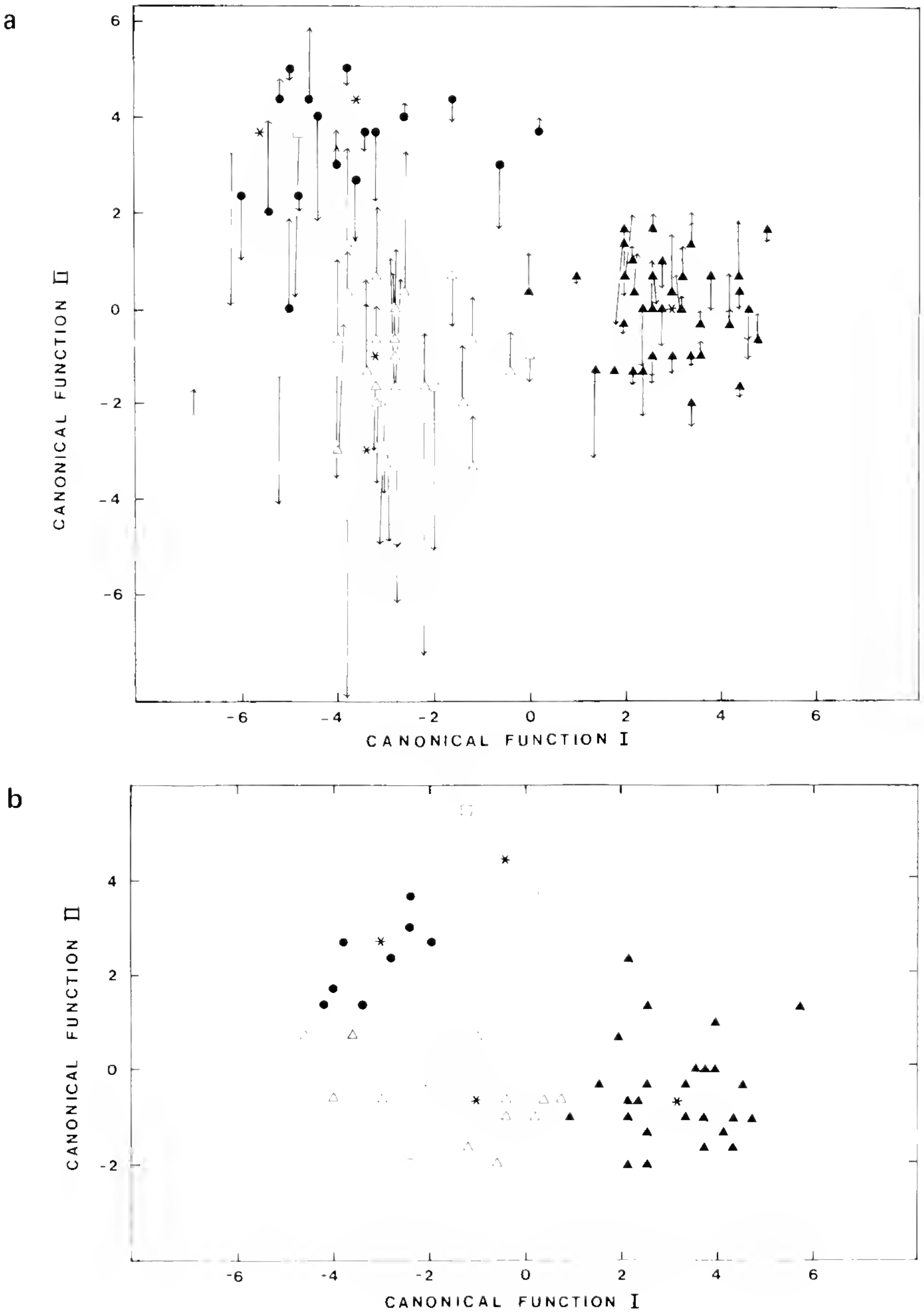

Figure 12 Discriminant function clusters of skull characters of *S. murina* (△), *S. dolichura* (▲), *S. gilberti* (○), *S. griseoventer* (●), and *S. aitkeni* (□): (a) males, (b) females. *, group means. In males, increased separation is achieved with canonical function III (arrows) which are drawn to the same scale as funtion I & II.

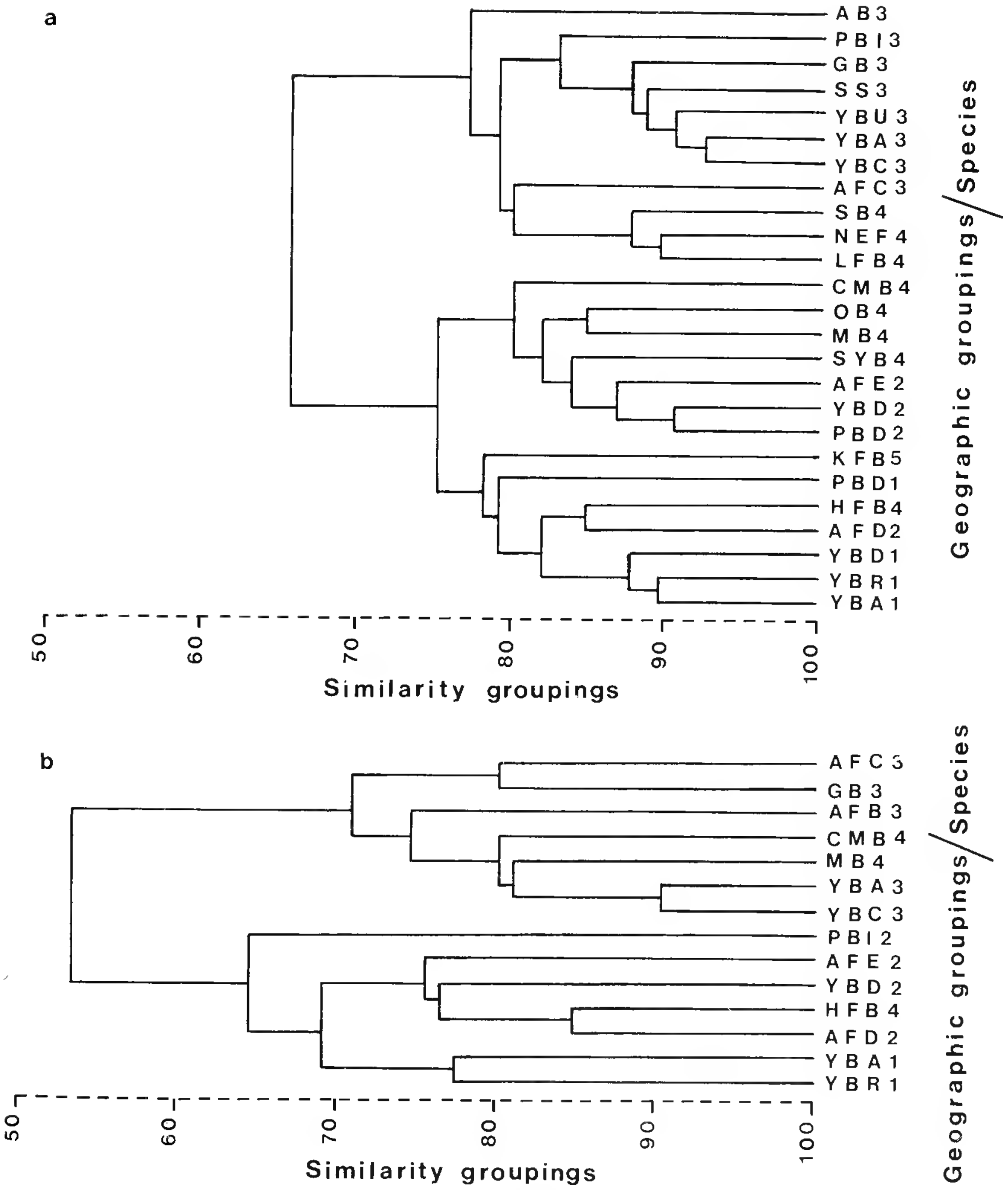

Figure 13 Dendrogram of phenetic relationships of the five species of *Sminthopsis* according to their geographic groupings (a) males; (b) females. For explanation of geographic group alpha codes see Figure 3; the suffixed species numeric code is as follows: 1, *S. gilberti;* 2, *S. griseoventer;* 3, *S. dolichura;* 4, *S. murina;* and 5, *S. aitkeni.*

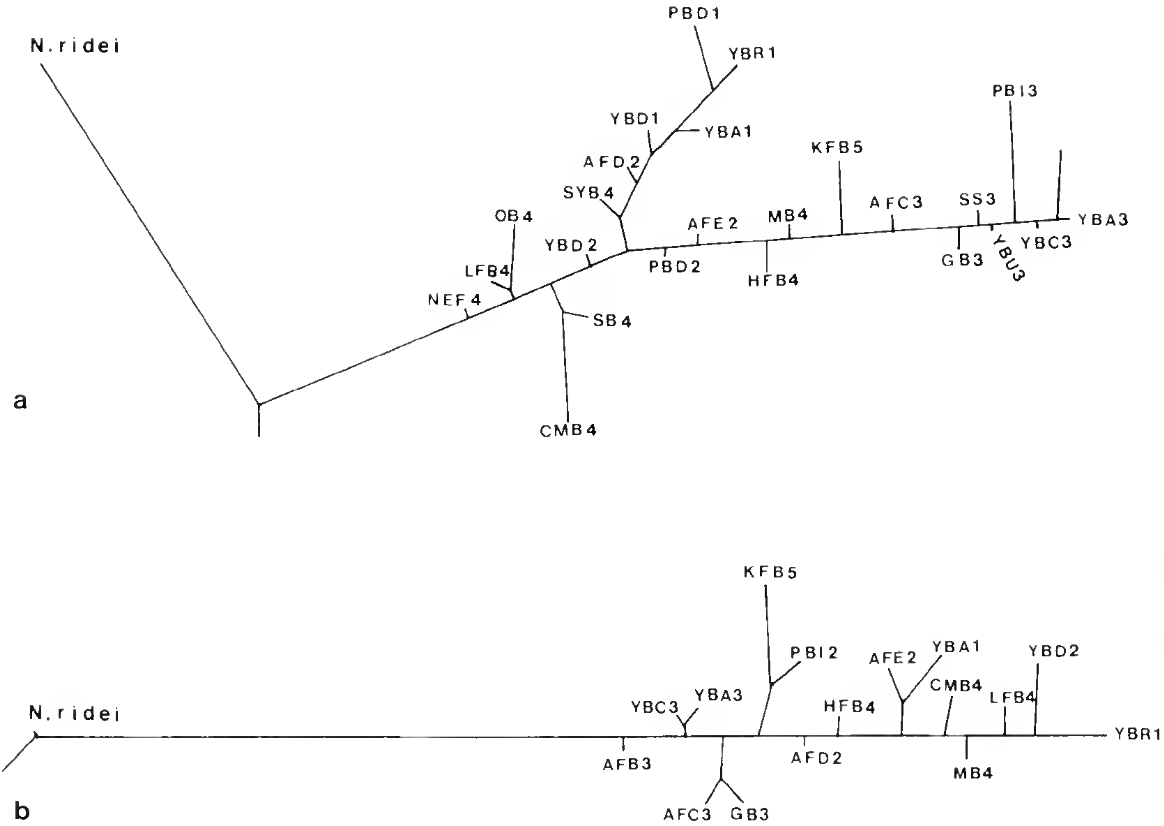

Figure 14 Wagner tree of the five species of *Sminthopsis* according to their allocation into geographic groups, constructed from raw means of all variables except tragus and weight. (a) males. (b) females. Branch lengths are proportional to patristic distances. For explanation of geographic group alpha codes see Figure 3; the suffixed species numeric code is as follows: 1, *S. gilberti;* 2, *S. griseoventer;* 3, *S. dolichura;* 4, *S. murina;* and 5, *S. aitkeni.*

General Discussion

In agreement with our previous study of dasyurid morphometrics (Kitchener *et al.* 1983) the extensive data set covering 22 craniometric and five external morphological characters resolves into a few components able to account for most variation. Foremost amongst these is a size factor accounting for approximately half the total variance, being highly correlated with most characters, particularly the craniometrics. Overall size is often considered an unsuitable character for use in systematics, due to the confounding effects of nongenetic factors such as environment and age. However, in this case the contribution of overall size to morphological discrimination of species, grouped primarily by the traditional approach, is substantial, as judged by the discriminant analysis. Accurate placement of animals into five putative species is effected in the majority of cases using the identification criteria of Table 4.

A purely morphometric appraisal of the systematics of the *Sminthopsis* OTUs provides good support for a monophyletic origin of only two of the five putative species. These two are *S. gilberti* and *S. dolichura.* However, due to the dependence of this classification on size characteristics and the problems of morphometric characters in general (Kitchener *et al.* 1983), it is not certain whether this monophyly represents a true monophyletic origin or merely a distinctiveness of derived characters resulting from occupying a unique environment. A general lack of monophyly for the other species groups precludes the use of these Wagner trees in testing hypotheses concerning vicariance biogeography following the methods of Platnick and Nelson (1978).

Further similarity to the *Ningaui* situation (Kitchener *et al.* 1983) arises from the discordant systematic predictions of male and female character sets. In an attempt to resolve some of the contradictions between male and female classification and also between the traditional and numerical classifications, the continuous morphometric variables were gap-coded to produce additive binary characters. In some instances these characters represent a better estimate of the underlying genetic structure (Sneath and Sokal 1973). This was unsuccessful and in both male and female cases the new classifications are still widely variant and are more similar to Wagner trees constructed from raw data than to each other. We can only surmise that there may be substantially different selective pressures on the morphology of male and female dasyurids, which may account in part for the extensive sexual dimorphism.

One facet of nearly all Wagner trees, and somewhat less so of the phenograms, is the division of *S. murina* into two groups. A group generally to the east and south of the Great Dividing Range, composed of the NEF, LFB, OB, SB and CMB OTUs which is close to the hypothesised ancestor of the *S. murina* (*sensu* Archer 1981) group, and a group comprising individuals from the Murray Darling Basin OTU (MB) and Mount Molloy, north-eastern Queensland OTU (HFB); this group is situated on the branch of the Wagner tree giving rise immediately to *S. aitkeni* and later to *S. dolichura.* On this basis there may be cause for a taxonomic subdivison of *S. murina (sensu stricto)*, although further study of morphometrics and other characters, such as biochemical genetic characters, are needed before the validity or taxonomic level of this split can be assesed.

The HFB OTU is very similar to individuals from Tolga, approximately 64 km to the south, which have previously been accorded subspecific status *(S. murina tatei).* Generally individuals in the HFB and MB OTUs are distinguishable from other *S. murina* populations by their generally longer tails (80.6 and 79.9 mm, respectively) which are normally longer than their nose to vent lengths. Also they frequently have a short inter-palatal distance (3.2 and 3.1 mm, respectively). The HFB individuals also have short bullae (4.8 mm).

Sminthopsis aitkeni by virtue of having only one population is unable to be tested for monophyly; but its substantial separation, reflected by patristic distance, from other *Sminthopsis* OTUs agrees with our proposed placement of this form as a distinct species.

Probably the most fragmented group on the Wagner tree is *S. griseoventer.* Although the OTUs assigned to *S. griseoventer* are not greatly separated when assessed through patristic difference, they do arise from three distinct branches of the male and female Wagner tree.

These numerous instances of disagreement between the traditional and numerical classifications must result from either, differences in their data inputs or, differences in interpretation of these data, or perhaps both. The various attributes of classificatory techniques, with respect to the way their underlying concepts interpret systematic data, are copiously documented in journals such as *Systematic Zoology*. A reiteration of these phenomena is unnecessary here as their characteristics are independent of the animal group for which they are employed.

While the results of different classificatory schemes using similar data sets have been shown to produce disparate results both in the general case (see for example Rohlf and Sokal 1981) and specifically for carnivorous marsupials (Kirsch and Archer 1982), innate characteristics of data sets may, in some cases, swamp distinctions in classificatory technique. The degree of congruence between the phenetic and phylogenetic classifications of both males and females for raw, gap-coded and 'size free' data most probably reflects the properties of our morphometric data set. This data set of 27 variables for each OTU may be flawed for use in numerical taxonomy in a number of ways: (a) morphometric variables may be substantially altered by non-genetic factors, such as environment; (b) these variables may also be subject to intense natural selection (for instance Morton and Alexander [1982] suggest that tail length of *S. crassicaudata* is selected on the basis of the adaptiveness of food storage in various environments); (c) the coding of morphometric variables to reflect genetic characters is notoriously difficult; (d) our 27 variables respond to a much smaller number of underlying factors (as seen in the principal components analysis) and a single change in one factor will be weighted by the number of times that factor is replicated (thus size differences play major roles in determining the placement of OTUs on trees); (e) as *Sminthopsis* is rarely abundant, many values of character for OTUs are based on a few, often one or two, individuals.

As numerical taxonomic studies require numerous independent characters to be effective, the iteration of a few underlying factors (d) is probably the most serious flaw. Future studies of small mammals should expand their character sets to include more non-craniometric characters.

That cladistic analyses commonly have trouble with data sets such as used here is emphasised by Kirsch and Archer's (1982) inability to find monothetic groupings for any carnivorous marsupial taxa and is probably also responsible for the large amounts of homoplasy apparent in their Wagner trees. One assumption in applying Wagner analysis to phylogeny reconstruction is that the characters used must be conservative with respect to change (Felsenstein 1978). It may be that, as a result of selective forces and non-genetic influences, many morphometric characters used here violate this assumption.

Traditional taxonomic approaches must also rely on morphological characters; however these approaches, often by virtue of their subjectivity, make less rigorous demands on their data; for instance their dependence on fewer characters allows them to ignore much of the iteration of single factors. In addition, they are also able to employ some characters, such as colour, which are exceedingly awkward to include in numerical approaches.

In no way can these findings be construed to suggest that the *principles* of traditional mammalian taxonomy are superior to those of more recent taxonomic theories; rather we would suggest the converse to be true. Instead, this should be seen as a difference in operationality, given the current constraints of collection and coding of morphometric data from the rare small marsupials. Neither should it be taken to suggest that morphometric criteria be abandoned, for they may contain information on reproductive isolation, thus speciation, not available through other characters: in this case the tentative division of *S. murina* (*sensu* Waterhouse). This study emphasises that morphometric characters should continue to be used in marsupial taxonomy. However, they should first be subjected to extensive univariate and covariate analyses, and research into mechanisms to transform them into parameters which more accurately characterise gene pools should be a primary consideration.

Nomenclatural Note

Because *S. fuliginosa* is a possible available name for one of the species of *Sminthopsis* recognised in this study, we have found it necessary to detail our findings regarding aspects of the 'holotype' of *S. fuliginosa*, particularly doubts concerning the provenance of its type locality and the material selected to represent the type.

Previous authors (Thomas 1888, Tate 1947, Troughton 1965, Archer 1981) have referred to BM 44.2.15.20 as the holotype of *S. fuliginosa* (Gould, 1852). However, Gould specified no example in his type description apart from providing several body measurements and an illustration of the externals. BM 44.2.15.20 is more correctly termed a lectotype, which was designated as such by Thomas (1888).

The name *Sminthopsis fuliginosa* (Gould, 1852) cannot be assigned to any of the three new species described herein from Western Australia for the following reasons:

Lectotype skull. Much of the posterior part of the skull of lectotype of *A. fuliginosus* BM 44.2.15.20, a young adult male, is missing (see stereopair photograph in Archer [1981: 96]). Measurements presented by Archer (1981: 88) of the remains of this lectotype skull and the dentaries, particularly C^1_1-M^4_4, M^1_1-M^4_4, M^1_1-M^3_3, length from posterior edge of articular condyle to anterior edge of $I_{\overline{1}}$ alveolus ($DCI_{\overline{1}}$) and distance from ascending ramus to articular condyle (CONRAM) would exclude *S. gilberti* and *S. griseoventer*, but fall within the range of measurements for *S. dolichura*. The absence of developed entoconids on $M_{\overline{1}}$-$_{\overline{4}}$ in the holotype (Archer 1981, Figure 16 and Archer pers. comm.) and confirmed by Hill (pers. comm.) also excludes *S. griseoventer*.

Lectotype skin. Gould's (1852, letterpress P1.41) type description of *S. fuliginosa* states that 'the whole of the upper surface dark greyish brown interspersed with numerous longer black hairs, giving it a fuliginous or sooty hue... the sides of the chest sooty grey, separated down the centre by a narrow line of buffy grey extending from the chin to the insertion of the forelegs; undersurface pale greyish white.'

Of the three species under consideration, only *S. griseoventer* could be described as having the chest 'sooty grey' but neither *S. griseoventer*, *S. gilberti* or *S. dolichura* have a 'narrow line of buffy grey extending from the chin to the insertion of the forelegs.' Gould's description of 'undersurface pale greyish white' would better match *S. gilberti* and *S. dolichura* than *S. griseoventer* which is a grizzled grey colour.

J.E. Hill (pers. comm.) describes the colour of the underparts of the lectotype of *S. fuliginosa* as follows: 'Overall this is best described as greyish white, with the white element predominating. The underside of the chin to the lower lip and posteriorly to the base of the throat has a moderate covering of whitish hairs, only faintly tinged with grey. Under the microscope this covering is insufficiently dense to wholly conceal the underlying skin: the hairs are rather short and woolly. Pelage of this nature extends just to the sides of the throat where the hairs become longer, denser, to have a dark, slaty base extending for nearly half their length, with a whitish tip, and to be interspersed with occasional longer, brownish guard hairs. The chest has a relatively dense cover of similarly dark based, white tipped hairs. The pelage over the belly from a line just anterior to the last ribs to and including the inguinal region is longer, almost lank: the hairs have dark, slaty grey bases, the dark colour extending for about one third to one half of their length, and are generously and liberally tipped with greyish, almost creamy white. Pelage of this nature extends to and just on to the flanks. The greyish undercolour is not completely obscured by the white tipping but shows through on the anterior part of the belly and on the chest to give a more or less "mottled" effect: posteriorly the grey is more totally obliterated and the pelage appears on the surface to be more clearly greyish white.' This description would fit *S. gilberti* and *S. dolichura* but not *S. griseoventer* in which the dark base of the hair of the underparts is more than three-quarters of its length and tipped with a light grey colour.

Gould's (1852) type description of *S. fuliginosa* states that both the length of the tail and length of the nose to root of the tail (measures approximating nose to vent and tail to vent) are 3¼ inches (= 83 mm). Measurements of the holotype (Hill pers. comm.) record the length of the tail to vent and snout to vent as 86.2 and 94.0 mm, respectively. However, Hill considered that in recent times 'skull measurements may have been distorted during the extraction of the skull.' The measurements match those of *S. griseoventer* and *S. gilberti* but not that of *S. dolichura*. The length of the tarsi and toes in the type description of *S. fuliginosa* is ⅝ inches (= 15.9 mm) which falls within the range of measurements of *S. griseoventer* and *S. dolichura* but not *S. gilberti*.

Type locality. Gould (1852, letterpress to Pl.41) does not state the type locality of *S. fuliginosa* but notes that the species is very abundant in King George Sound and vicinity of Perth. Thomas (1888: 305), 'R. Avon, W.A.' Tate (1947: 121), 'River Avon, King George's Sound, Western Australia.' Troughton (1965) considers that J. Gilbert's actual collection locality was 'Toodyay on the Avon River, 15 miles from Northam.' He attributes this error in location by Tate (1947) to result from Gould (1852) 'giving the local name "Twoor-dong-aborigines of King George's Sound" at the heading of his description of the "Sooty Antechinus".' Archer (1981) reports that the label on the 'holotype' is not the original and gives the locality as 'R. Avon. W.A.' Hill (pers. comm.) 'according to the register, the specimen came from "hill sides on the banks of the Avon".'

Gould's (1852) type description of *S. fuliginosa* clearly relates to, and closely paraphrases, Gilbert's (in Whittell 1954) notes on the 'Twoor-dong' accompanying his specimen No. 37 collected from King George Sound. Gilbert stated that the 'Twoor-dong' 'so much resembles that (species) found at Perth that I first considered them to be identical... (however) it not only differs in its mode of making a nest and other habits, but is very much darker, having the cheeks paler, while the underside is not so pure a white.' Gilbert referred to the Perth species as 'Dtam-in' and states that 'I only know of two habitats for this species (Dtam-in), viz. the grass lands of Toodyay Valley and in the groves of *Xanthorrhoea* surrounding the swamps and lakes around Perth. Gould (1852, letterpress to Pl. 42) described the "Otam-in" [*sic*] as *Sminthopsis albipes* (Waterhouse). Gilbert (in Whittell 1954) stated that the "Dtam-in" is rarely seen or met with in small families as is the nearly allied species "Twoor-dong" from King George's Sound.'

This last statement by Gilbert implies that the 'Twoor-dong' as recognised by him was restricted to King George Sound. Gilbert provided Gould with much of his natural history information and is paraphrased by Gould on the distribution of the 'Twoor-dong' and 'Dtam-in.' It is, then, possible that Gilbert's King George Sound specimen no. 37 is the basis of the type description o f *S. fuliginosa* and that this, not Toodyay, is the type locality. Interestingly, Archer (pers. comm.) when examining specimens in the British Museum for his revision of *Sminthopsis*, recorded measurements of three *Antechinus fuliginosus* Gould, 1852, 'syntypes' from King George Sound, Western Australia which were glued to a board. Hill (pers. comm.) states 'that this board is BM(NH)46.4.4.59-61 with 1 skull, 2 rostra, 2 mandibles and labelled "King George's Sound *Antechinus fuliginosus* Gould 1852." Further, this board is marked on the back by Gray "306 c.d.e.", "Antechinus. W. Australia," "46.4.4.59-61," "No. 37 of my list Gould," in another hand "probably fuliginosa," in another hand "Phascogale crassicaudata" and in yet a fourth, modern hand "37 of Gilbert's List is 'Twoor-dong' of King George Sound see Whittell (1954) W. Aust. Nat. **4:** 108-9." On the front of the board this same hand has written "*Antechinus fuliginosus* Gould, 1852," "King George Sound," "SYNTYPES," "46.4.4.59-61" while Gray has also written "W. Australia." Our old Register (i.e. Gray's temporary Register) makes it quite clear that no skins were ever received: in the main Register the specimens are each annotated "No. 37." Another specimen, BM(NH)53.10.22.25 comes from Toodyay and was also presented by Gould.' However, Thomas (1888) lists only three specimens of *S. murina (sensu lato)* collected by J. Gilbert from Western Australia, including the holotype of *S. fuliginosa;* none of these listed specimens is from King George Sound.

Lectotype history. Hill (pers. comm.) suggests that at one time during the last century the skin had its skull inside it and have been a 'mounted animal.' He states that 'existence of the rostrum only tends to support this opinion since at the time that it was collected many collectors cut off the skulls in this way and left them in the skin.' Thomas (1888) lists the lectotype as 'Ad. sk.' witb no mention of the skull which tends to confirm Hill's suggestion that at that time the skull or what was left of it was still in the skin. Hill considers it possible, then, that in its early days this specimen was exposed to light and also that its measurements may have been distorted during the extraction of the rostral fragment. Furtber, the lectotype has neither Gilbert's collecting number nor its original label attached. However, the label attached to tbe skin of the lectotype of *S. fuliginosa* states 'Fig.'d as *Ant. albipes* in Voy. Ereb. Terr. E.G. (from photo of type skin provided by J.E. Hill and fide' M. Archer).

In conclusion, while the rostral part of the skull of the lectotype of *S. fuliginosa* is very similar to *S. dolichura*, the dimensions and colour of the pelage, on which the type description is based, is not *S. dolichura* and cannot confidently be ascribed to either *S. griseoventer* or *S. gilberti.* It is, then, possible tbat we have not examined specimens of *S. fuliginosa* in this revision, and that more extensive collecting in the region of King George Sound will provide examples of this taxon. In this regard the unique specimen referred to earlier, WAM M7945, is coastal in the south-west, has no entoconids, and has body measurements similar to those in the type description of *S. fuliginosa*, as well as skull and dentary proportions similar to the lectotype of *S. fuliginosa.* However the skin of WAM M7945 could not be preserved to compare with the type description of *S. fuliginosa.* Nevertheless, of the specimens examined WAM M7945 best represents *S. fuliginosa.*

Another possibility is tbat tbe lectotype BM (NH) 44.2.15.20 selected by Tbomas (1888) is not a syntype, for it differs from the type description as follows: the pelage of the cbest has no medium buffy stripe or hairs tbat are noticeably 'sooty grey'; the nose to root of tail lengtb is much longer than that of the type description – altbough this may be due to stretcbing of the skin as a result of the later removal of the skull; and it was apparently collected near the Avon River, Toodyay and not from King George Sound or in the vicinity of Perth.

It is possible, but by no means certain, that Gould's type description was based on the skins associated with the skulls and dentaries collected by J. Gilbert from King George Sound (his No. 37). However, it is not possible to distinguish Gilbert's No. 37 from other parts comprising BM(NH) 46.4.4.59-60. Also the skins associated with these parts are lost and apparently were never presented to the British Museum (Natural History). Although many of the diagnostic characters of these skulls and dentaries are absent througb damage, and the sex of the parts is not known, tbe comprehensive measurements of them, kindly provided by M. Archer, indicate a real possibility that the dentaries and skulls comprise different taxa. For example, interpalatal vacuities are long (4.0 to 4.5 mm), indicating *S. griseoventer* – while the single CONRAM to M_{1}-$_{4}$ ratio (0.70) is very low, indicating *S. gilberti.* The $M^{\underline{1}}$-$^{\underline{4}}$: $M_{\overline{1}}$-$_{\overline{4}}$ ratio for all combinations available (on the assumption that the dentaries may not be correctly matebed with the skulls) of 0.867, 0.881, 0.883, 0.897, 0.898 and 0.914, are outside the minimum values of *S. griseoventer* or *S. gilberti* (see Table 1). They are, however, similar to the values expected from the ratio of average $M^{\underline{1}}$-$^{\underline{4}}$ lengths of *S. griseoventer* to average M_{1}-$_{4}$ lengths of *S. gilberti* (0.909). Also, small to moderate entoconids are present on M_{2}-$_{3}$ of one set of dentaries but are absent from the other.

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Revision of *Denisonia suta* (Serpentes: Elapidae) and the Description of a New Species Closely Related to It

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Abstract

Variation in *Denisonia suta* is analysed and a new, closely related species (*D. ordensis*) is described from the far north-east of Western Australia and adjacent part of Northern Territory. The genera *Denisonia* and *Rhinoplocephalus* are redefined.

Introduction

It was recently discovered that *Denisonia suta* was represented in the valley of the Ord River by two variants. Two specimens agreed with material from Central Australia and further south and east. The other twelve specimens were larger and darker, lacked a hood and ocular stripe, and had more numerous ventrals and the nasal widely separated from the preocular. Did the latter represent a new species? If so, was it conspecific with any of the five nominal species synonymized with *D. suta* by Loveridge (1934: 286)?

In order to answer these questions I examined all the material in the Western Australian Museum (specimens prefixed with WAM); South Australian Museum (SAM); National Museum of Victoria (NMV); CSIRO Division of Wildlife, Canberra (ANWC); Australian Museum, Sydney (AM); Queensland Museum (QM); Central Australian Wildlife Collection, Alice Springs (NTM/AS); and Northern Territory Museum, Darwin (NTM).

Three more specimens of the strange variant came to light, extending its known range south to Sturt Creek and east to the Victoria River, but there were no more examples of typical *suta* from that region. However, I was able to satisfy myself that two taxa coexisted on the Ord and that the new species had not been previously named. It now remains to discuss the generic placement of the snakes.

Worrell's dismemberment of *Denisonia* in 1961 was for a long time ignored by systematists. Nevertheless Boulenger's concept of the genus clearly required amendment. In 1970 McDowell established a new genus, *Salomonelaps*, for *D. par* of the Solomon Islands. In 1982 I transferred *D. coronata* and its closest relatives to *Notechis*. The remaining Western Australian species of *Denisonia* (*sensu* Boulenger 1895) can be placed in one or other of two genera, *Denisonia* and *Rhinoplocephalus*, which are now redefined.

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Denisonia Krefft, 1869. Type-species: *D. ornata* Krefft, 1869 [= *D. maculata* (Steindachner, 1867)]. Other species: *D. atriceps* (Storr, 1980); *D. devisi* Waite and Longman, 1920; *D. fasciata* Rosén, 1905; *D. ordensis* sp. nov.; *D. pallidiceps* (Günther, 1858); *D. suta* (Peters, 1863). Small to medium-sized elapid snakes with broad depressed head, no canthus rostralis, undivided anal and subcaudals, 15-21 midbody scale rows, pale iris and vertically elliptic pupil. Further distinguishable from *Rhinoplocephalus* by non-opalescent lower surfaces and neck distinctly narrower than head; and from *Notechis* by whitish rather than black concealed skin between dorsals and strongly imbricate scales on sides of body. Confined to Australia, mainly the north and east.

Rhinoplocephalus Müller, 1885. Type species: *R. bicolor* Müller, 1885. Other species: *R. dwyeri* (Worrell, 1956); *R. flagellum* (McCoy, 1878); *R. gouldii* (Gray, 1841); *R. monachus* (Storr, 1964); *R. nigriceps* (Günther, 1863); *R. nigrostriatus* (Krefft, 1864); *R. punctatus* (Boulenger, 1896); *R. spectabilis* (Krefft, 1869). [It is thus the *Denisonia gouldii* group of Storr (1981) plus *R. bicolor;* the latter has long been the sole member of *Rhinoplocephalus*, but its only peculiarity is the absence of internasals.] Small elapid snakes with broad depressed head, no canthus rostralis, undivided anal and subcaudals, 15-17 midbody scale rows, dark iris and circular pupil. Further distinguishable from *Denisonia* by opalescent-white lower surfaces and neck little or not narrower than head; and from *Notechis* by the highly glossed scales and whitish (rather than black) concealed skin between dorsals. Confined to Australia, mainly the south.

Systematics

Denisonia suta (Peters, 1863)

Hoplocephalus sutus Peters, 1863: 234. Buchsfeld, S.A.
Hoplocephalus frenatus Peters, 1870: 646. Lake Elphinstone, Qld.
Hoplocephalus frontalis Ogilby, 1890: 1027 Narrabri, N.S.W.
Hoplocephalus stirlingi Lucas and Frost, 1896: 149. Charlotte Waters, N.T., etc.
Denisonia frontalis var. *propinqua* DeVis, 1905: 51. Qld.
Denisonia Forresti Boulenger, 1906: 440. [Near Alexandria, N.T., *fide* Boulenger, 1908: 333.]

Diagnosis

A small slender to large stout *Denisonia* with 19 (rarely 17 or 21) midbody scale rows. Distinguishable from *D. atriceps* by brown (not black) hood and fewer subcaudals (24-42, v. 46-48).

Description

Snout-vent length (mm): 133-775 (N 420, mean 333.3). Length of tail (% SVL): 10.4-17.7 (N 410, mean 14.4).

Rostal very slightly to much wider than high. Internasals much smaller than prefrontals. Frontal 1.2-2.2 times as long as wide and 1.6-2.6 times as wide as supraoculars; sides usually straight and slightly converging backwards. Nasal a little to much wider than high; in contact with preocular (N 188) or separated (227). Preocular considerably higher than wide; widely separated from frontal. Postoculars 1 (N 2, when upper fused to supraocular), 2 (339) or 3 (1, when lower divided); lower usually (77.5%) longer and narrower than upper. Temporals 1+2 (N 3), 2+2 (223), 2+3 (16), 3+2 (1), 3+3 (2) or 3+4 (1); primaries considerably larger than secondaries; lower primary usually (65.5%) largest, descending deeply between last two labials but never completely separating them. Upper labials 5 (N 1, when third and fourth partly fused) or 6 (339). Lower labials 7 (N 336) or 8 (1). Dorsals strongly imbricate, much longer than wide. Scale rows at midbody 17 (N 7), 18 (1), 19 (337), 20 (4) or 21 (4); on neck 19 (2), 20 (3), 21 (39), 22 (58), 23 (191), 24 (21) or 25 (15); immediately before vent 12 (3), 13 (200), 14 (40), 15 (84), 16 (1), 17 (2). Ventrals 135-180 (N 331, mean 156.0). Subcaudals 24-42 (N 327, mean 32.2). Ventrals plus subcaudals 165-218 (N 327, mean 188.2).

Typical coloration. Top of head and first 5-8 transverse scale rows on neck greyish-brown, tending to become blackish-brown peripherally, i.e. at contact with ocular stripe and with dorsal coloration. Remaining upper surfaces pale greyish-brown, scales finely edged with greyish-brown or blackish-brown. Broad, irregular whitish ocular stripe from internasal to temple. Narrower, irregular, often discontinuous, blackish-brown loreotemporal stripe from top of rostral through top of upper labials and bottom of temporals to side of neck. Lips and lowest dorsals mostly whitish. Mental and chin-shields smudged with greyish-brown. Remaining lower surfaces whitish.

Darker variants. Dorsals basally to wholly greyish-brown (in latter case hood may be imperceptible). Pale ocular stripe partly to completely invaded by greyish-brown pigment. Outer tenth to third of ventrals anteriorly edged with greyish-brown. Regionally a greyish-brown mid-ventral stripe and much less frequently a dark vertebral stripe.

Distribution

Widespread in the warmer and drier parts of northern and eastern Australia: eastern Northern Territory north to the Roper River; Queensland (mainly interior) north to Chillagoe; interior of New South Wales; northern and north-western Victoria; eastern South Australia south to the Murray Mallee; and an apparently isolated population in the extreme north-east of Western Australia (Ord River).

Geographic Variation

Over its enormous range *D. suta* undergoes much variation, most of which is clinal. It will be seen from Table 1 that snout-vent length and the number of ventrals, subcaudals and dorsal scale rows just before the vent, increase from south to north; whereas frequency of nasal contacting preocular and relative length of tail decrease from south to north. (For comparison, the corresponding data for *D. ordensis* are also tabulated.)

Coloration varies non-clinally. In Central Australia, South Australia, north-western Victoria, western New South Wales and south-western Queensland, most specimens are pale and consequently the hood and facial pattern are moderately to strongly developed. In northern Victoria, eastern New South Wales and south-eastern Queensland, north to Wandoan and west to Glenmorgan, Mungindi, Nyngan, Hillston and Boort, darker variants predominate; here alone, as in the type of *Hoplocephalus frontalis,* a dark mid-ventral stripe may be present. In northern and central Queensland coloration is highly variable, ranging from pale and well-patterned to dark and almost patternless. Snakes from the north-east of the Northern Territory are similarly variable but dark, almost patternless individuals predominate, at least on the Barkly Tableland (which is also notable for the great length and girth of many specimens).

Table 1 Mean snout-vent length (mm), relative length of tail (% SVL), number of dorsal scale rows immediately before vent, number of ventrals, number of subcaudals and frequency (%) of nasal in contact with preocular for *D. suta* in six States or regions and for *D. ordensis*; sample size in parentheses.

	SVL	Tail	Dorsals before vent	Ventrals	Subcaudals	Nasal contacting preocular
Victoria (10)	253	15.0	13.2	140.6	29.1	66.7
New South Wales (149)	292	15.0	13.4	147.9	31.6	56.0
South Australia (62)	299	14.4	13.6	153.9	32.1	51.5
Queensland (97)	353	14.4	13.7	159.8	33.2	31.3
Central Australia (61)	355	12.8	13.7	162.7	30.2	52.6
NE of Northern Territory (40)	498	13.9	14.3	167.2	35.0	8.1
ordensis (15)	469	13.6	14.9	175.6	34.1	0.0

Material

Western Australia

Kununurra (WAM 20568); Lake Argyle (WAM 58875).

Northern Territory

Roper Hwy, 52 km E Stuart Hwy (AM 80338); 57-60 km SW Borroloola (ANWC 947-50); 40-48 km W Eva Downs (NTM AS 1916-7); Anthony Lagoon and vicinity (NTM AS 504; NTM 4794-6, 4819-20, 5209, 5235); Brunette Downs (ANWC 920; NTM AS 3224-5); 20 km N Alroy Downs (NTM 8561, 9584, 9687-9, 9700); No. 26 Bore, Alroy Downs (NTM 9522-3, 9719-21, 9728, 9762-4); Alexandria (NTM AS 576-7), Gallipoli (NTM AS 520-1); Barkly Hwy (NTM AS 522); 7 km W Avon Downs (NTM AS 594), Barkly Hwy at Qld border (NTM AS 483); Hatches Creek (SAM 3487); Utopia (AM 65230); No. 3 Bore, Woodgreen (NTM AS 81); 50 km N Alice Springs (NTM 6568), Milton Park (NTM AS 4156); Kunoth Bore (NTM AS 90); 10-16 km N Alice Springs (NTM 726-32); Alice Springs (WAM 55423, 70946; SAM 2777, 3145, 13442, NMV D50544; AM 49845, 51946-8; NTM AS 91-4, 1069, 1397, 1498, 2275, 3226, 3239, 4807, 5893-4; NTM 317, 333, 497, 1868, 1958, 2456-7, 3802); Undoolya (NTM AS 629); between Alice Springs and Box Hole Crater (SAM 3580); 16 km S Alice Springs (NTM AS 1080) and 16 km SW (NTM AS 1498); Ormiston Reserve (NTM AS 116); Jay Creek (NTM 535); Owen Springs (WAM 20830); Todd River Station (NTM AS 1396); Ringwood (NTM AS 95); Hermannsburg (SAM 2323; NTM AS 96); Mereenie (NTM AS 1024); 29 km S Alice Springs (NTM 739-41) and 51 km S (NTM 498); Reedy Creek (24°18'S, 131°36'E) (NTM AS 1905); Maryvale (NTM 1958); Idracowra (SAM 3146); Charlotte Waters (NMV D11758, syntype of *Hoplocephalus stirlingi*).

Queensland

'Cairns district' (AM 80905); Chillagoe (QM 13447); Almaden (AM 10091); Normanton (ANWC 3173); Doomadgee (SAM 3820, 5331); 'Croydon' (QM 32289); St Ronans (QM 31071); Alice River near Townsville (QM 27640); near Townsville (SAM 3811); Ayr (AM 37372); Charters Towers (QM 6265); Hughenden (QM 4376, 13599, 15574); Prora, Nelia (QM 37204); Mt Isa (AM 25983, 26597) and 67 km E (NTM 8797); 12 km SSE Dajarra (AM 75903); Corfield (QM 7610); Winton (QM 26989, 27473); Pathungra (AM 58501); 21-mile Bore, Cazna Downs (QM 21605); Slashers Creek, 80 km E Boulia (QM 37012); Whyrallah (QM 39444); 160 km SW Winton (QM 39482); Longreach (QM 6000, 8915, 22971, 23187, 39291) and 74 km NW (AM 63013), 16 km N (QM 27507), 40 km W (QM 23312) and 77 km S (QM 37151-2); 45 km W Barcaldine (AM 65982); Coreena (QM 110); 10 km N Jericho (QM 9557); Clermont (QM 1223); Retro (QM 6117); Capella (QM 5799); Emerald (NMV D8651) and 12 km N (QM 36785), 15 km W (QM 36787) and 51 km E (QM 24143); Emerald Downs (AM 58498-9); 40 km S Blackwater (QM 36786); Rockhampton (ANWC 2699); Sandringham (AM 87744, 92733); Bedourie (NTM 8805); Ruthven, Isisford (QM 6151); 16 km E Emmet (WAM 55876); Castle Creek (QM 4568); Jundah (QM 10581); Cuddapan (ANWC 2803); Birdsville (QM 9896) and 8 km NW (QM 10276); Augathella (QM 7555); Cattle Creek, Wandoan (QM 15338); 'Gundiah' (QM 2287); Jackson (QM 7483, 9111); Roma (QM 28700); Muckadilla (QM 6574); Amby (QM 23184); Quilpie (QM 5091, 28444, 28446); Eromanga (QM 5329); Claverton Park, Wyandra (QM 3811); Glenmorgan (QM 37206); Tara (QM 23164); Jimbour (QM 3874); Macalister (QM 10245); Dalby (QM 8706, 9614); Bowenville (QM 2913-6, 2919); Oakey (QM 2707, 28958); Pampas (QM 2729); St George (QM 34604); Gilruth Plains, Cunnamulla (AM 58500, 64978-9); Binya, Cunnamulla (QM 23196); Cunnamulla (AM 17126); Dynevor Downs (QM 25966); Thargomindah (QM 5048, 26417); Warwick (QM 10243); Byra (ANWC 1784).

South Australia

Near Goyders Lagoon (SAM 22559); Innamincka (SAM 18158; NMV D9198) and 60 km N (SAM 20838), 30 km N (SAM 21006), 25 km NW (NMV D41575), 14 km W (SAM 20534), 38 km W (SAM 16118); Murta Murta Well (SAM 19852); Etadunna (WAM 44941; SAM 16020 *a-b*); Coober Pedy (AM 17183-5); SE of Coward Springs (SAM 11101; ANWC 2546); 26 km W Marree (SAM 18857); 20 km NE Billa Kalina (SAM 20995) and 5 km NW (SAM 20994); Old Moolawatana (SAM 12440); Lyndhurst (SAM 2598); Andamooka (SAM 19843); Wooltana (AM 93434); Leigh Creek (SAM 3147 *a-c*); Moolooloo (SAM 928); N of Blinman (SAM 3916); Pimba (SAM 20544-6) and 11 km S (SAM 20543); Mern Merna (SAM 2628*a*, 2658); Wilpena Pound (SAM 3264); Whittata (SAM 2781); Bookaloo (SAM 1691 *a-c*); south end of Lake Torrens (SAM 3831, 3873); Milang Ruins (SAM 14908); Gordon (AM 19205); Quorn (SAM 130); Nonning (SAM 14727); Port Augusta (SAM 4055; NMV D50543; AM 17180); Mambray Creek (SAM 22552, 23266); Orroroo (SAM 1469); near Point Lowly (SAM 20857); Whyalla (SAM 15172); Port Pirie (SAM 3725); Cowell (SAM 12794); Canegrass (SAM 21527); Copeville (SAM 1339 *a-b*); 'Penong' (SAM 2373); 'Aldgate' (SAM 2257 *a-b*); 'Halletts Cove' (SAM 2382).

New South Wales

Maxland, Mungindi (AM 14899); between Mungindi and Collarenebri (AM 99377); Goodooga (AM 12595); Wombeira, Goodooga (AM 12607); Moree (AM 1125-6, 1140*b*, 1407, 1489-90, 1493, 1623, 1836-7) and 6 km W (AM 93288); Pallamallawa (AM 14665); Delungra (AM 12246); Quantambone (AM 12207); Brewarrina (AM 17908, 18326, 20293) and 7 km E (AM 47345) and 32 km S (47344); Bourke (AM 97145, 97148) and 16 km N (AM 60312) and 80 km W (ANWC 2529); Milparinka (AM 14653, 14656-8, 42726-7); Calindary (ANWC 532, 534, 540); Wonaminta (AM 14654); Lake Bancannia (AM 32783); Peri Lake (AM 49194-5); Louth (NMV D7566; AM 14393); Drildool (AM 12513); Narrabri (AM 8527); Bundarra (AM 2751, 28258); Upper Manilla (AM 13416); Garryowen, Curlewis (AM 13978); Coonamble (AM 75905); Quambone (ANWC 2649; AM 95271) and 22 km SSW (AM 76337); Willie, Macquarie Marshes (ANWC 2629; AM 92389); Warrumbungle Mountains (AM 15623, 18891); Armatree (AM 59923); Spring Ridge (AM 46026); Mootwingee (AM 45539); Wilcannia (SAM 12067-8; AM 37755, 46027-8); Manara, 125 km W Cobar (AM 76554-7); Warrah, Willow Tree (AM 7115, 7190); Gilgandra (AM 26583) and 24 km W (AM 32891-3, 32968-70, 37378-9, 37422, 41160-1, 46025); 15 km NW Warren (QM 37824); Nyngan (AM 65317) and 24 km SE (ANWC 2528); 38 km WNW Nevertire (AM 60310-1) and 29 km WNW (AM 60309), 20 km WNW (AM 60308), 16 km WNW (AM 64279); Dunedoo (AM 79137); Werrana, Merriwa (AM 8996); near Broken Hill (NMV D40131; AM 46034, 46037); Kinchega National Park (AM 32797); Euabalong West (AM 11557); Lake Cargelligo (AM 8849); Hillston (AM 100044); Yandembah (AM 783, 968-71); 32 km S Condobolin (AM 45285-6); Tregalana, Forbes (AM 4230); Lake Cowal (ANWC 106, 139, 1481-2); Woorandara, Booligal (ANWC 1521-30, 2874); Wyalong (AM 98696); Bribbaree, Temora (AM 18949, 18954, 18957); Young (AM 24676); Lake Victoria (NTM 5032); 24 km NNE Wentworth (NMV R13810, D40172); Hay

(AM 15418); Leeton (AM 9744, 12545, 14407*a-b*, 15691); Glen Era, Darlington Point (AM 7303); Coleambally (AM 95507); Widgiewa (AM 14409); Nyang (NMV D3703); Jerilderie (NMV D13392); Momolong (NMV D15355); Caldwell (NMV D8637; AM 14018-20); Barham (NMV D9258, 54672-3).

Victoria

Red Cliffs (NMV D48908); Kulkyne (NMV D55110); 'Mallee' (NMV D4757); Kerang (NMV D15354) and 8 km NE (NMV D57084); Quambatook (AM 11550-1); 13 km W Boort (NMV D14400); Kewell (NMV D3600); Kamerooka (NMV D15353).

Denisonia ordensis sp. nov.

Holotype

WAM 58877, collected by W.H. Butler on 9 January 1972 at Argyle Downs, W.A., in 16°17'S, 128°47'E.

Paratypes

Western Australia

Kimberley Research Station (WAM 12344, 22352); Argyle Downs (WAM 58873-6, 58878-9, 76626); Gordon Downs (NTM 314).

Northern Territory

Rosewood (WAM 37701-2); Wave Hill (NTM/AS 561-2).

Diagnosis

A large *Denisonia*, very like *D. suta*, but with little or no indication of hood or pale ocular stripe and with lower surfaces narrowly cross-banded with greyish-brown and white.

Description

Snout-vent length (mm): 385-662 (N 15, mean 468.9). Length of tail (% SVL): 12.3-15.3 (N 15, mean 13.6).

Rostral wider than high. Internasals much smaller than prefrontals. Frontal 1.3-1.9 times as long as wide and 1.8-2.7 times as wide as supraocular; sides usually straight and converging backwards. Nasal much wider than high and separated from preocular (N 15). Preocular considerably higher than wide; widely separated from frontal. Postoculars 2 (N 15); lower longer and narrower than upper. Temporals 2 + 2 (N 15); primaries considerably larger than secondaries; lower primary largest and descending deeply between last two labials but never completely separating them. Upper labials (N 15). Lower labials 7 (N 15). Dorsals strongly imbricate, much longer than wide. Scale rows at midbody 19 (N 15); on neck 21 (3), 22 (3), 23 (8) or 24 (1); immediately before vent 13 (N 1) or 15 (14). Ventrals 169-181 (N 15, mean 175.6). Subcaudals 30-38 (N 15, mean 34.1). Ventrals plus subcaudals 200-218 (N 15, mean 209.7).

Upper and lateral surfaces greyish-brown except for indistinct pale blotches on lips and less frequently on lores and temples. Lower surfaces whitish except for brownish-grey mental, chin-shields, first three lower labials and anterior half of ventrals and subcaudals.

Distribution

Far north-east of Western Australia south to Gordon Downs, and far north-west of Northern Territory south-east to Wave Hill.

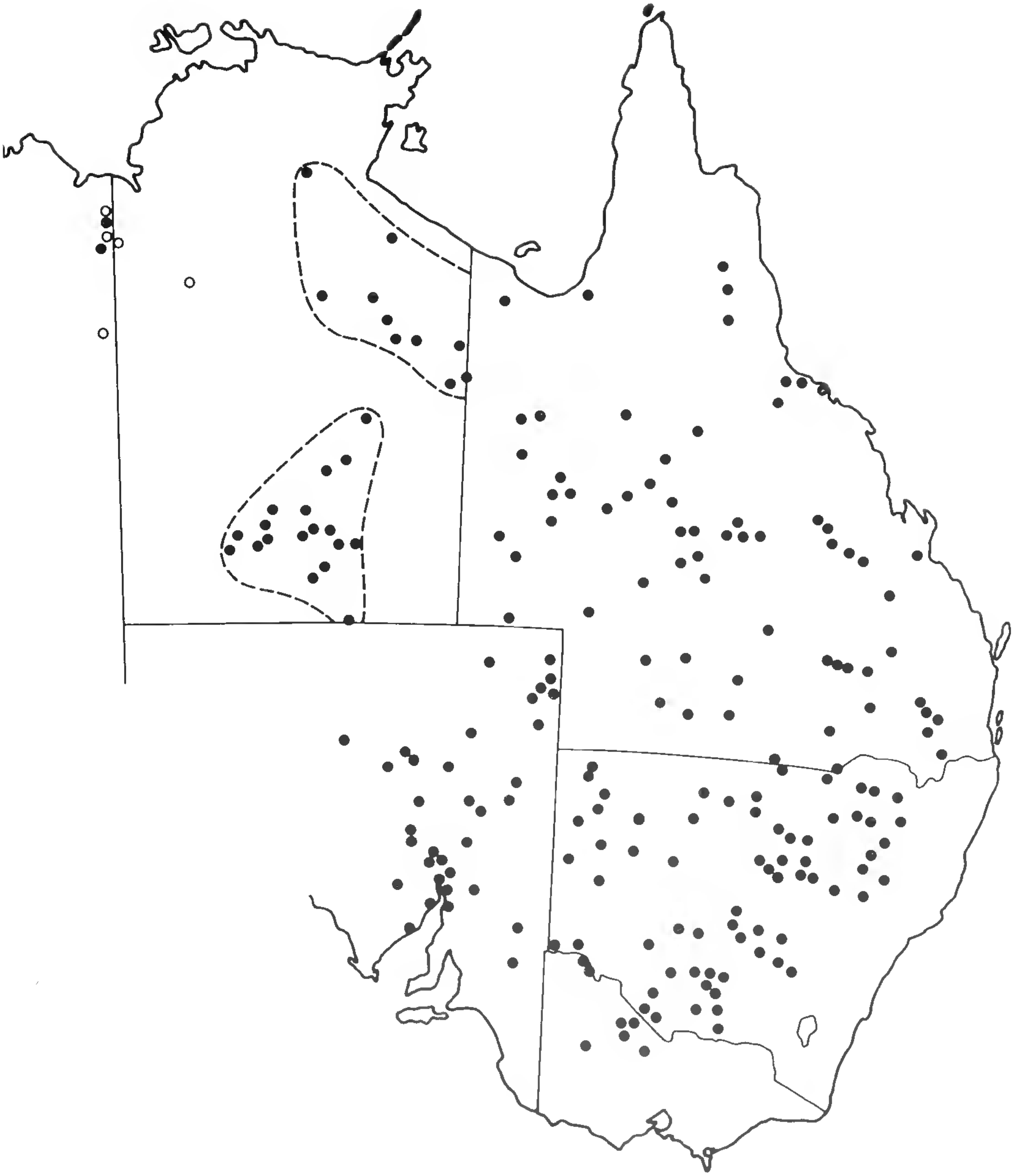

Figure 1 Map of northern and eastern Australia showing location of specimens of *D. suta* (solid circles) and *D. ordensis* (open circles). The broken lines indicate the limits of the north-eastern Northern Territory populations and Central Australian populations, the presumed ancestors of *ordensis* and Ord River *suta* respectively.

Remarks

Before describing this species, I had to be convinced that the two Ord River specimens taken to be *suta* were not in fact part of the variation in *ordensis*. This was especially important in view of the wide and continuous variation in pattern in the geographically nearest populations of *suta*, i.e. those inhabiting the north-east of the Northern Territory. Here, specimens from the periphery of the region (the Roper and McArthur Rivers and the Queensland border) were well-patterned, whereas most specimens from the core of the region (the Barkly Tableland) approached *ordensis* in the feeble development of the hood and ocular stripe. However, in all other respects the material seemed to be uniform, and there was no reason for doubting that only one species occurred in the north-east of the Territory.

The situation was different within the range of *ordensis*. While a few specimens of *ordensis* had some indication of a hood or ocular stripe, none lacked crossbands on the lower surfaces. Variation in pattern was thus not continuous. Moreover the two specimens of *suta* differed from *ordensis* in three scale characters. The nasal in both *suta* was in contact with the preocular; it was separated in all 15 *ordensis*. In both *suta* there were 13 dorsal scale rows immediately before the vent; only one *ordensis* had 13 rows, the rest had 15. The *suta* had 162 and 165 ventrals, compared to 169-181 in *ordensis*. The probability that these correlations were due to chance must be very low.

It seems that the north-east of Western Australia has been colonised by two different stocks of *suta*: one from the Barkly Tableland, the other from Central Australia (see map, Figure 1). The latter migration is presumably the more recent, for there is yet no discernible difference between Ord River and Central Australian specimens. Incidentally, the pathway between these regions, perhaps no longer extant, could have been used by the skink *Ctenotus alacer*.

In isolation *ordensis* has diverged slightly in morphology from its presumed ancestor, the Barkly Tableland population of *suta*. Whether it has acquired reproductive isolation is of course unknown. Nevertheless, if a line is drawn between two species it can only be drawn here, for there is little doubt that the Barkly population is conspecific with *suta*. Distribution and variation are continuous in eastern Australia, and specimens resembling those from the Barkly Tableland have been examined from as far south in Queensland as Longreach and as far east as the Townsville district.

Finally there is the question, how can two such similar species as *ordensis* and *suta* coexist in the valley of the Ord? Presumably they occupy different habitats, but in the absence of label data, one can only make a guess. Mine is that *ordensis* (and the dark variants of *suta*) prefer black-soil plains and flats, and Ord River *suta* (and pale variants elsewhere), lighter soils.

Acknowledgements

For the loan of specimens I am grateful to T.D. Schwaner (SAM), A.J. Coventry (NMV), J.C. Wombey (ANWC), R. Sadlier (AM), J. Covacevich (QM), M.R. Hewett (NTM/AS) and P. Horner (NTM).

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Some Sphaeromatid Isopods (Crustacea) from Southern and South-western Australia, with the Description of a New Genus and Two New Species

K. Harrison*

Abstract

The taxonomy of some sphaeromatid isopods from southern and south-western Australia is discussed. In the subfamily Sphaeromatinae: *Cymodoce longicaudata* Baker is designated the type species of *Platynympha*, gen. nov.; *Waiteolana gibbera*, sp. nov. is described from Western Australia, and the genus *Waiteolana* Baker is shown to be hemibranchiate, not platybranchiate as previously thought. In the subfamily Dynameninae: *Moruloidea tumida*, sp. nov. is described from Western Australia, and *Envallentinia darwinii* (Cunningham) (not known from Australia) and *Cassidinopsis tasmaniae* Baker are transferred to *Moruloidea* Baker (*Envallentinia* Stebbing becoming a junior synonym of *Moruloidea*); the genus *Pseudosphaeroma* Chilton is shown to be eubranchiate, not hemibranchiate as currently believed, and *P. campbellense* Chilton is recorded from Australia for the first time; *Cassidinopsis tuberculata* Sivertsen and Holthuis (from the South Atlantic) is transferred to the genus *Pseudosphaeroma*, while *Pseudosphaeroma barnardi* Monod (from Africa), *P. callidum* Hurley and Jansen (from New Zealand) and *P. jakobii* Loyola e Silva (from Brazil) are excluded from this genus; *Amphoroidella* Baker and *Platycerceis* Baker are formally raised to full generic rank and generic diagnoses are provided. The genus *Artopoles* Barnard (from Africa) is transferred from the sub-family Cassidininae to the subfamily Dynameninae.

Introduction

Since Baker's work on the Sphaeromatidae (1908, 1910, 1911, 1926, 1929) and Hale's (1929) review of the South Australian species, few taxonomic studies have considered the Australian members of this family in detail. Recently, however, the present author has been involved in an intensive investigation of the sphaeromatid fauna of Queensland (e.g. Holdich and Harrison 1980, 1981a, 1981b, 1983; Harrison and Holdich 1982a, 1982b). During the course of that study a number of collections containing specimens from other regions of Australia were examined. Some of these specimens belonged to species which were new to science, while others illustrated taxonomic points of relevance to the family as a whole. The present paper considers some of these specimens.

In the following descriptions the terms platybranchiate, hemibranchiate and eubranchiate occur. Bowman (1981) and Iverson (1982) replaced the incorrectly formed subfamily names Platybranchiatinae, Hemibranchiatinae and Eubranchiatinae with correctly formed names.

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However, as the older terms are in general use and are widely understood, they will be retained here as vernacular descriptive terms (with no nomenclatural status) to indicate the presence or absence of transverse folds on pleopods 4 and 5, i.e. platybranchiate, all rami lacking transverse folds; hemibranchiate, with only the endopods folded; and eubranchiate, with all rami folded. Within this family, members of the subfamily Cassidininae are platybranchiate, members of the Sphaeromatinae are hemibranchiate, and members of the Dynameninae are eubranchiate.

Systematics

Order Isopoda Latreille, 1817
Family Sphaeromatidae Milne Edwards, 1840
Subfamily Sphaeromatinae Milne Edwards, 1840

Genus *Platynympha* gen. nov.

Type Species

Cymodoce longicaudata Baker, 1908.

Diagnosis

Hemibranchiate. Endopod of pleopod 3 lacking branchial folds. Body moderately flattened. Cephalosome with median rostral process not obvious in dorsal view. Coxal plates of pereonites and lateral margins of pleon as separate, curved, acute extensions. Pleon bearing two long, straight, parallel sutures at each side, extending to postero-lateral angle. Pleotelsonic apex with marked notch bearing median tooth. Antennular peduncle article 1 with postero-distal angle extended distally as long acute process. Pereopods 1 to 3 with superior surfaces of ischium and merus bearing, at most, several short setae or spines. Pleopod 5 exopod with apex and internal margin of distal article covered with fine teeth; anterior surface of distal article bearing long, projecting, toothed boss; medio-distal angle of proximal article bearing two small toothed bosses. Uropod with rami sub-equal, styliform, extending well beyond pleotelsonic apex. Sexual dimorphism not obvious.

Adult Male

Penes slender, tapering, separate to base. Appendix masculina arising from medio-proximal angle of endopod of pleopod 2 and extending well beyond ramal apex. Maxillipedal palp articles 2 to 4 bearing pronounced setigerous lobes.

Ovigerous Female

Mouthparts metamorphosed; mandibles partially fused with cephalosome, incisor and molar processes absent; maxillule as two simple lobes; maxilla as three simple lobes; maxillipedal endite expanded proximally as setigerous lobes, palp not reduced but lobes short, lacking setae. Brood pouch formed from four pairs of oostegites arising from pereonites 1 to 4 and overlapping in mid-line. Anterior pair of oostegites each with longitudinal fold, such that anterior region of oostegite covers posterior mouthparts. Brood not housed in marsupium thus formed, but held in five pairs of internal pouches. Ventral pockets absent.

Remarks

Platynympha gen. nov. differs from the genus *Cymodoce, sensu stricto* (as defined in Harrison and Holdich, in press) by the smooth nature of the body, the form of the coxal plates, the form of the lateral and posterior margins of the pleon, the structure of the pleotelson, the form of the epistome, the structure of the antennules, the more elongate posterior pereopods, the form of the uropods, and in lacking sexual dimorphism.

Platynympha does not closely resemble any other known hemibranchiate genus. This genus currently contains only the type species, *P. longicaudata*, from South Australia.

Etymology

Greek, *Platus* + *nympha*, i.e. flat nymph (feminine). (In Greek mythology Cymodoce was a nymph, and this genus is founded for a species currently housed in the genus *Cymodoce* Leach.)

Platynympha longicaudata (Baker, 1908), comb. nov.

Figure 1

Cymodoce longicaudata Baker, 1908: 139, 140, 160, pl. 3; – Hale, 1927: 319; – Hale, 1929: 287, 288; – Nierstrasz, 1931: 201.

Material Examined

Blanche Harbour (16 km south of Port Augusta), South Australia. On fine sand beach with *Zostera* sp. and *Posidonia* sp. Lower shore. 4 adult males, 3 sub-adult males, 2 ovigerous females, 2 non-ovigerous females, 2 immature specimens, 24 juveniles. Coll. G. Hartmann, 05.xii.1975. (Zoological Museum, University of Hamburg). – Proper Bay, Port Lincoln, South Australia. South end of bay among *Posidonia* sp. mixed with algae. 1 non-ovigerous female, 1 juvenile. Coll. G. Hartmann, 04.xii.1975 (Zoological Museum, University of Hamburg). Type specimens are housed in the South Australian Museum.

Description

Adult Male

Dorsal surface smooth, lacking tubercles and setae. Coxal plates of pereonites 1 to 6 long, curved, acute; coxal plates of pereonite 7 short, broadly rounded. Lateral margins of pleon curved, acute; posterior margin smoothly arcuate. Pleotelson sub-triangular, flattened, lacking anterior dome; posterior half with median longitudinal carina. Apex of pleotelson with broad shallow notch bearing elongate, acute, median tooth extending well beyond notch margins; posterior half of pleotelsonic carina extending full length of apical tooth.

Antennular peduncle article 1, postero-distal extension extending almost to distal margin of article 2; peduncle article 2 with pronounced, acute, dorsal tooth; 24-articled flagellum extending to level of pereonite 3. Antenna with 24-articled flagellum extending to level of pereonite 6. Epistome apex truncate; each postero-lateral extension terminating as acute conical spine. Mandibular incisor processes dentate; left mandible with lacinia mobilis

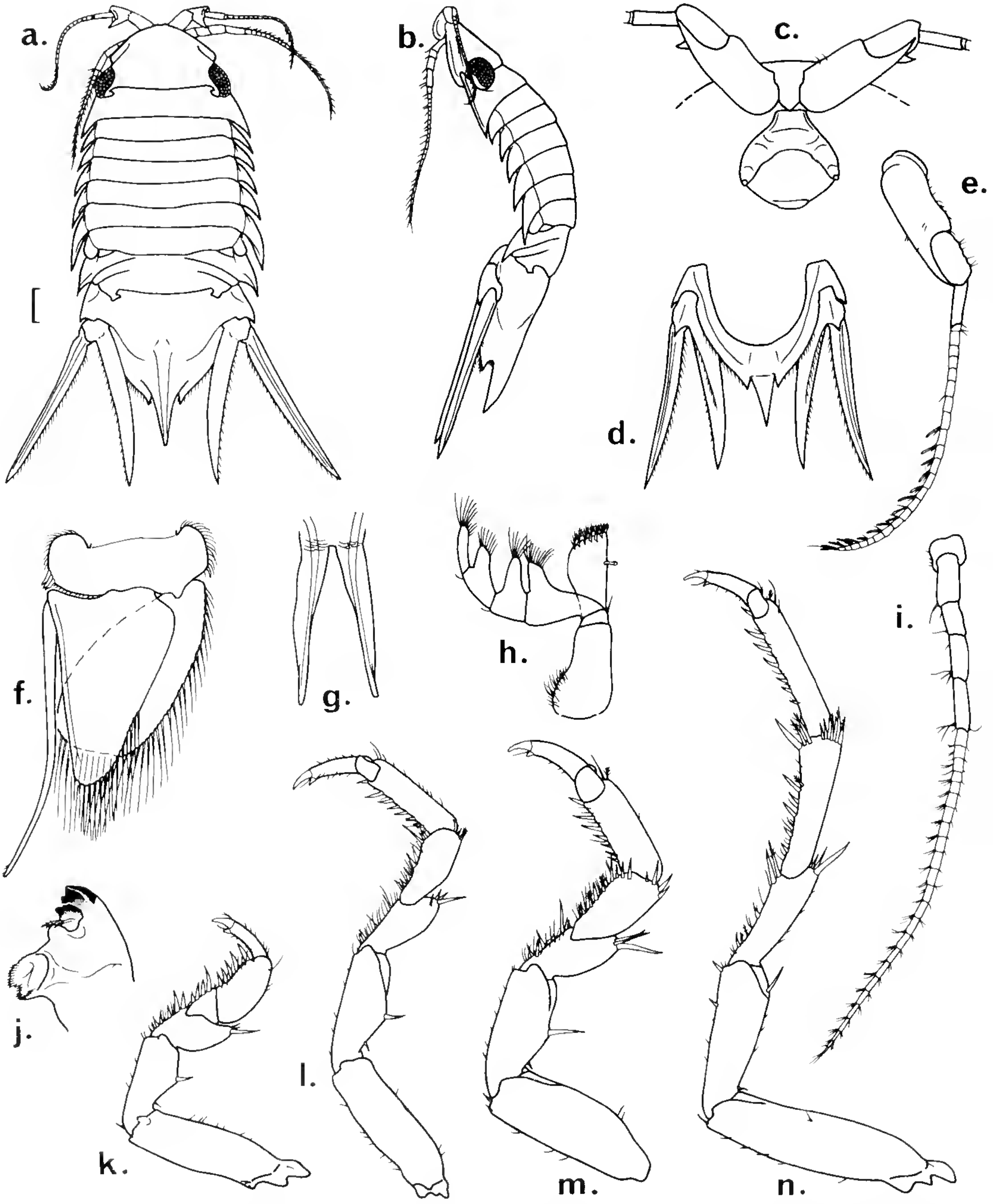

Figure 1 *Platynympha longicaudata* (Baker), comb. nov. Adult male, 11.9 mm; (a) dorsal; (b) lateral; (c) epistome, labrum and antennular peduncles, ventral; (d) pleotelson and uropods, ventral; (e) antennule; (f) pleopod 2; (g) penes; (h) maxilliped; (i) antenna; (j) left mandible; (k) to (n) pereopods 1, 2, 4 and 7 respectively. Scale line represents 1 mm.

dentate; mandibular palps well formed. Maxillular inner lobe with four pectinate spines; outer lobe with group of moderately slender, curved, simple spines. Maxilla with two outer lobes each bearing approximately nine slender curved spines; inner lobe bearing plumose spines. Maxillipedal palp articles 3 and 4 each bearing short, superior, distal seta. Pereopods becoming longer posteriorly; pereopod 7 very slender, almost twice length of pereopod 1. Penes each seven times as long as basal width, tapering to narrowly rounded apex. Pleopod 1 endopod just shorter than exopod; medial margin of endopod with longitudinal oblique groove; proximal lateral margin of exopod with long stout spine. Pleopod 2 rami similar to those of pleopod 1 but sub-equal in length; endopod lacking medial groove; exopod lacking lateral spine. Appendix masculina 1.5 times length of endopod, with three short, medial, sub-terminal setae. Pleopod 3 with endopod broad, sub-ovate, just shorter than sub-elliptical exopod, with medial margin straight; exopod with complete distal articulation. Bases of pleopods 1 to 3 each bearing three medial coupling hooks. Pleopod 4 endopod narrow, sub-elliptical, with deep, medial, sub-terminal notch; exopod sub-triangular with complete sub-apical articulation and several short terminal setae. Pleopod 5 endopod elongate, sub-reniform; exopod narrow with complete sub-terminal articulation and lateral fringe of short setae. Uropodal rami sub-equal.

Ovigerous Female

Resembling male except in sexual characters.

Non-ovigerous Female

As above but lacking brood pouch, and mouthparts not metamorphosed. Oostegites present as rudimentary 'buds.'

Sub-adult Male

Resembling non-ovigerous female but lacking oostegite 'buds' and bearing penes. Penes relatively shorter than those of adult male. Appendix masculina forming along medial margin of endopod of pleopod 2, but not free.

Immature Specimen

Resembling non-ovigerous female but lacking oostegite 'buds.'

Remarks

Specimens of this species bear a superficial resemblance to specimens of *Platycerceis hyalina* Baker (see below) but are easily distinguished by having a long median tooth in the pleotelsonic apical notch.

P. longicaudata has only been collected from eel-grass (*Zostera* sp. or *Posidonia* sp.) and can be common in certain areas. Hale (1927: 319), collecting in the Bay of Shoals, Kangaroo Island, said, 'This species was so plentiful in parts of the Bay that we were able to fill a quart bottle with specimens after half an hour of hand dredging amongst *Zostera*.'

Genus *Waiteolana* Baker, 1926

Waiteolana Baker, 1926: 276, 277; – Nierstrasz, 1931: 222; – Holdich and Harrison, 1981a: 634, 635.

Type Species

Waiteolana rugosa Baker, 1926.

Other Species

Waiteolana gibbera sp. nov. (Western Australia).
Waiteolana tuberculata Kussakin, 1967 (S.W. Atlantic Ocean).

Diagnosis

Hemibranchiate. Endopod of pleopod 3 lacking branchial folds. Both sexes with cephalosome, pereon and pleon lacking dorsal extensions. Pleon bearing two long sutures at each side; sutures extending to postero-lateral margin. Pleotelson evenly domed, lacking prominent ridges or bosses (but bearing tubercles or sculpturing in all known species). Pleotelsonic apex narrowly truncate, lacking notch, foramen, vertical incision or median extension; bearing very shallow, longitudinal, ventral depression. Each mandible with molar process modified as thin, narrow, acute cutting edge. Maxillipedal palp articles 2 to 4 bearing pronounced setigerous lobes. Pereopods 1 to 3 with superior surfaces of ischium and merus bearing, at most, several short setae or spines. Pleopod 5 exopod with two apical toothed bosses, one sub-apical medial boss, and two juxtaposed medial bosses. Uropodal endopod lamellar, at least twice length and twice breadth of reduced exopod. Sexual dimorphism not obvious.

Adult Male

Penes long, separate to base. Appendix masculina present, arising from medio-proximal angle of endopod of pleopod 2 and extending beyond ramal apex.

Ovigerous Female

Mouthparts not metamorphosed. Brood pouch formed from two pairs of oostegites arising from pereonites 3 and 4 and just overlapping in mid-line. Brood not housed in marsupium thus formed, but held in internal pouches (number not currently known). Ventral pockets absent.

Remarks

In this genus the mandible is markedly modified (cf. Baker 1926: 276). The molar process forms a small chisel-like blade, rather than a crushing or triturating surface, but as nothing is known of the feeding habits or food preferences of species in this genus, the purpose of these blades is not known.

Species of *Waiteolana* are known only from the south-east and south-western coasts of Australia (and possibly off the coast of Argentina – see Discussion).

Waiteolana gibbera sp. nov.

Figures 2, 3

Holotype

Adult male, 5.6 mm. Western Australian Museum Reg. No. 257-82. Coll. B.R.W., 04.ii.1962. From Garden Island, Western Australia (32°15′S, 115°09′E). Southern end of island. On gorgonians. Depth 3.5-4.5 m.

Paratypes

From type locality, collection details as for holotype. 7 adult males, 1 ovigerous female, 3 non-ovigerous females, 4 immature specimens (Western Australian Museum Reg. No. 68-80).

Description

Adult Male

Body deeply vaulted, lateral margins sub-parallel. Pereonites 1 to 4 dorsally arched (giving species its name). Posterior pereonites short and weakly ornamented in mid-line. Coxal plates of pereonites 2 to 7 separate, apically sub-acute with short longitudinal ridge; proximally each plate bearing prominent median tubercle. Pleon dorsally tumid with many low circular tubercles. Main dome of pleotelson weakly pronounced, bearing many scattered low tubercles; posterior region of pleotelson finely granulose, tapering to truncate apex.

Antennular peduncle articles smooth, not expanded anteriorly; 6-articled flagellum extending to level of pereonite 1. Antenna sub-equal in length to antennule; 8-articled flagellum extending to level of pereonite 1. Epistome sub-quadrate, anterior margin weakly emarginate, slightly projecting but not obvious in dorsal view. Labrum sub-circular with slight median distal notch. mandibular incisor processes markedly dentate; left mandible with lacinia mobilis tridentate. Maxillular lobes slender; outer lobe with approximately eight curved spines. Maxillar lobes slender, bearing sub-linear spines. Maxillipedal palp articles 3 to 5 bearing very short, fine superior setae. Pereopods robust, each with basis and ischium lacking superior spines; pereopods 2 to 7 each with merus and carpus bearing several superior distal spines. Penes each ten times as long as broad, distally narrow. Pleopod 1 basis bearing four medial coupling hooks; endopodal medial margin bearing longitudinal fold and fine, short, marginal setae. Pleopod 2 basis with three coupling hooks; endopodal medio-proximal angle acute, overlapping basis slightly. Appendix masculina narrow, 1.5 times length of endopod. Pleopod 3 basis with two coupling hooks; endopodal medial margin straight; exopod with complete distal articulation. Pleopod 4 endopod with apex obtusely angled, lacking plumose setae; exopod with complete distal articulation, apex lacking plumose setae. Pleopod 5 endopod sub-reniform; exopod with complete distal articulation. Uropodal endopod almost reaching pleotelsonic apex, sub-elliptical with sub-apical lateral notch; exopod 0.3 times length of endopod, sub-elliptical with lateral distal indentation.

Ovigerous Female

Resembling male except in sexual characters.

Non-ovigerous Female

As above but lacking brood pouch. Oostegites present as rudimentary 'buds.'

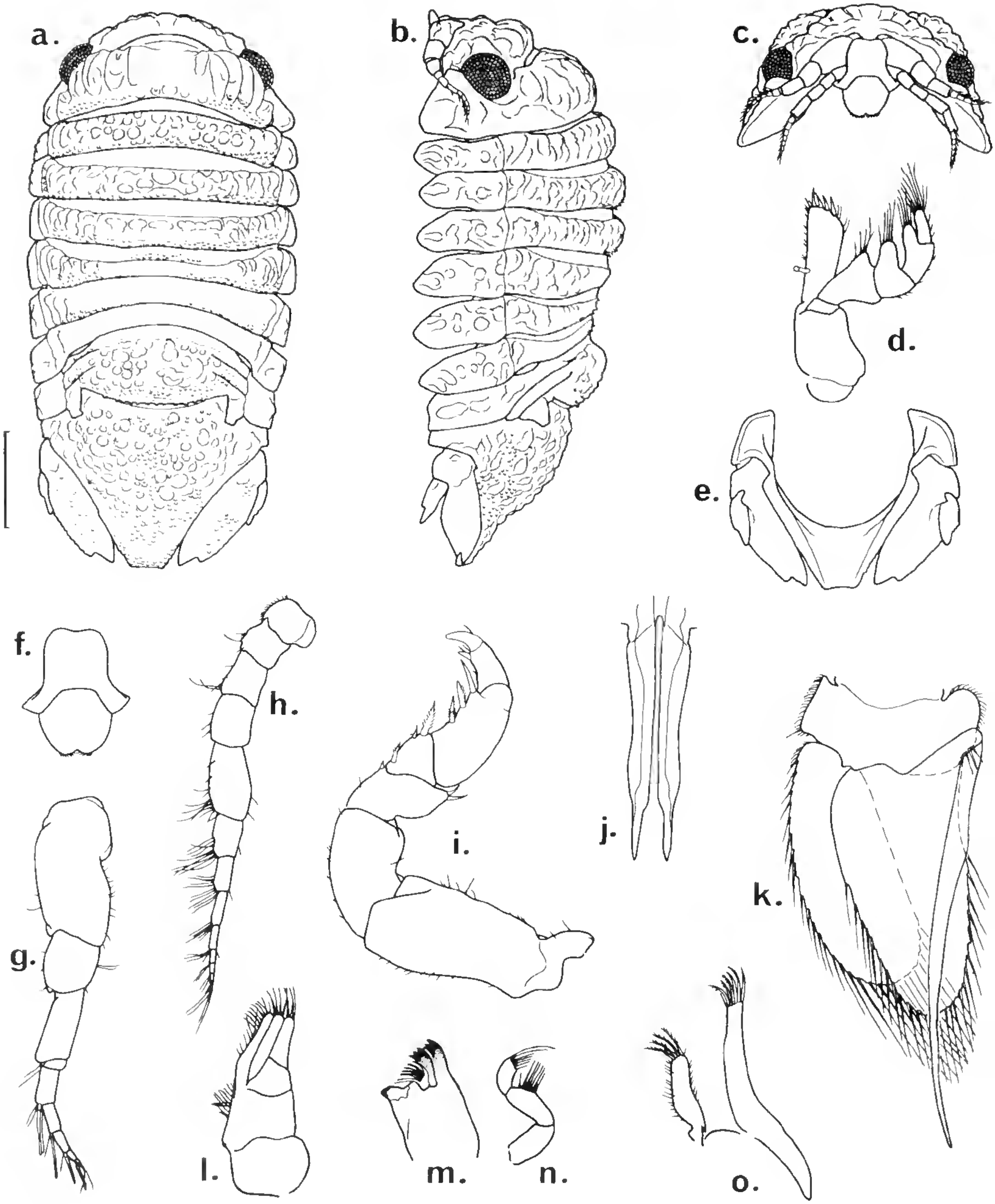

Figure 2 *Waiteolana gibbera* sp. nov. Adult male (paratype), 5.61 mm; (a) dorsal; (b) lateral; (c) anterior, ventral; (d) maxilliped; (e) pleotelson and uropods, ventral; (f) epistome and labrum; (g) antennule; (h) antenna; (i) pereopod 1; (j) penes; (k) pleopod 2; (l) maxilla; (m) left mandible; (n) mandibular palp; (o) maxillule. Scale line represents 1 mm.

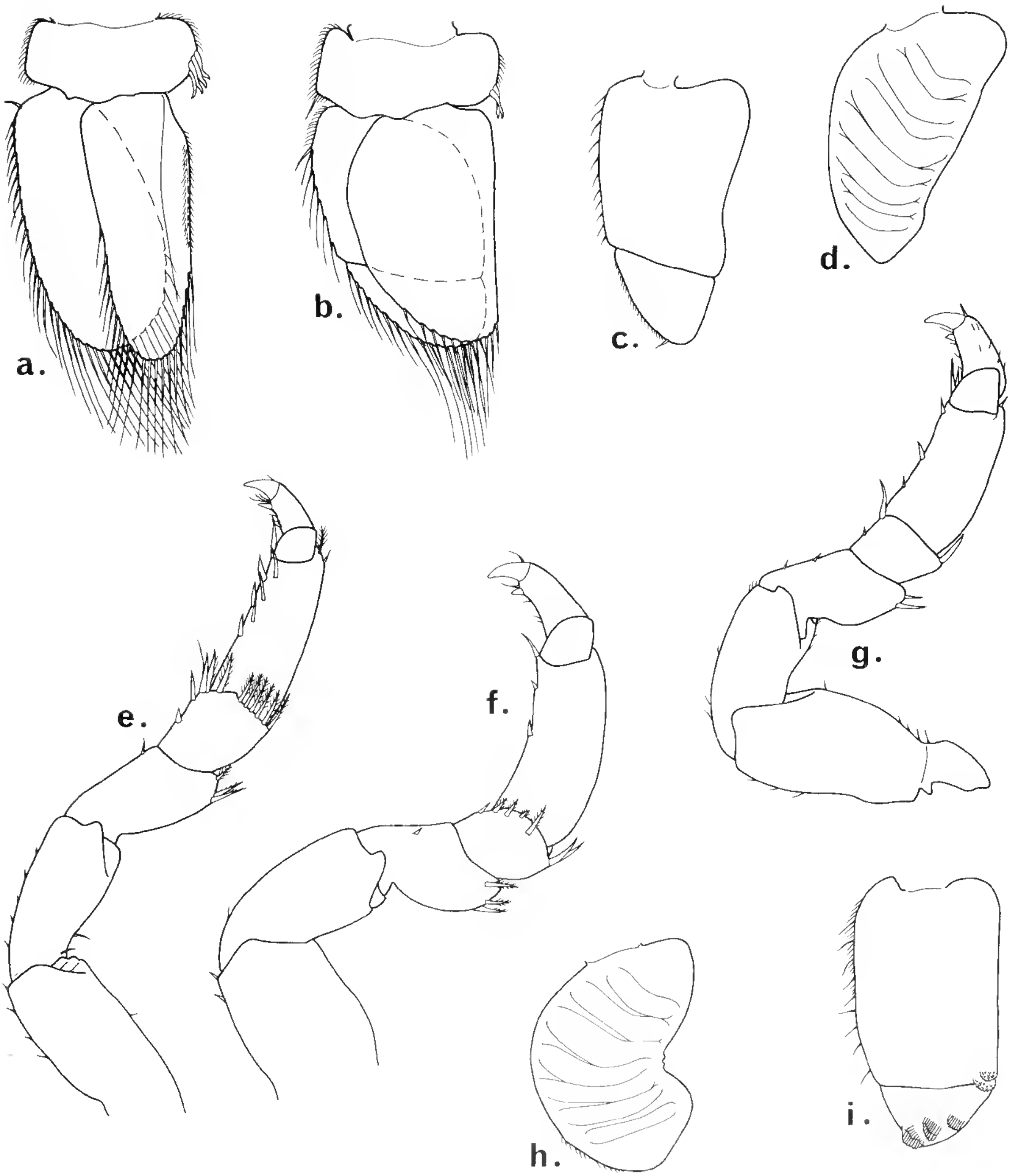

Figure 3 *Waiteolana gibbera* sp. nov. Adult male (paratype); (a) pleopod 1; (b) pleopod 3; (c) pleopod 4, exopod; (d) pleopod 4, endopod; (e) to (g) pereopods 7, 4 and 2 respectively; (h) pleopod 5, endopod; (i) pleopod 5, exopod.

Immature Specimen

Resembling non-ovigerous female but smaller and lacking oostegite 'buds' at bases of pereopods 3 and 4.

Remarks

W. gibbera can readily be distinguished from *W. rugosa* by its blunt, rather than apically acute, epistome, and by its apically narrower uropodal endopods. *W. gibbera* is known only from the shallow sub-littoral region of Garden Island, near Perth, Western Australia.

Etymology

Waiteolana + latin *gibbera* i.e. hump-backed.

Subfamily Dynameninae Bowman, 1981

Genus *Moruloidea* Baker, 1908

Moruloidea Baker, 1908: 150; Baker, 1926: 276; Hale, 1929: 292, 297, 298.
Vallentinia Stebbing, 1914a: 351. (preoccupied name) (new synonymy).
Euvallentinia Stebbing, 1914b: 944; – Barnard, 1920: 374; – Nierstrasz, 1931: 218; – Loyola e Silva, 1964: 3, 4. (new synonymy).

Type Species

Moruloidea lacertosa Baker, 1908 (South Australia).

Other Species

Moruloidea darwinii (Cunningham, 1871), comb. nov. (Argentina, Falkland Islands, Kerguelen).
Moruloidea tasmaniae (Baker, 1926), comb. nov. (Tasmania).
Moruloidea tumida sp. nov. (Western Australia).

Generic Diagnosis

Eubranchiate. Antennular peduncle article 1 not extended anteriorly as plate. Both sexes with pereon and pleon lacking dorsal extensions. Coxal plates of pereonite 5 expanded, overlapping those of pereonites 4 and 6 when body folded. Coxal plates of pereonites 6 and 7 with anterior margins concave. Pleon bearing two curved parallel sutures at each side; sutures extending to postero-lateral margin. Both sexes with both uropodal rami lamellar; exopod short, acute; endopod usually emarginate, but may be rounded (interspecific variation). Maxillipedal endite slender; palp articles 2 to 4 with pronounced, elongate, setigerous lobes. Pleopod 5 exopod with one apical toothed boss, one sub-apical boss, and two juxtaposed medio-distal bosses. Sexual dimorphism not pronounced.

Adult Male

Penes separate, short, with semi-circular tips. Appendix masculina narrow, arising from medio-proximal angle of endopod of pleopod 2 and extending beyond ramal apex; margins sub-parallel; tip rounded. Antennal peduncular articles robust; article 5 reflexed. Pereopod

1 very robust; propodus usually bearing pronounced, conical, inferior extension, but extension may be absent (interspecific variation). Dorsal tuberculation may be more pronounced than in female.

Ovigerous Female

Mouthparts not metamorphosed. Brood pouch formed from three pairs of narrow subequal oostegites arising from pereonites 2 to 4 and just overlapping in mid-line. Brood not housed in marsupium thus formed, but in four pairs of internal pouches. Ventral pockets absent. Antennal peduncle less robust than that of male; article 5 not reflexed. Pereopod 1 propodus lacking inferior extension.

Remarks

Due to the confusion surrounding this genus (see Discussion) the type species will be redescribed here.

Moruloidea lacertosa Baker, 1908

Figure 4

Moruloidea lacertosa Baker, 1908: 150, 151, 161, pl. 7; – Baker, 1929: 58, 61, pl. 1; – Hale, 1929: 297, 298.
Cassidinopsis lacertosa – Nierstrasz, 1931: 218.

Material Examined

St Vincent Gulf, South Australia. 1 adult male (Holotype, South Australian Museum Reg. No. C358), 1 subadult male (South Australian Museum Reg. No. C361).

Description of Adult Male Holotype

Dorsal surface of body granular, tuberculate. Pereonites 2 to 6 each with transverse row of low irregular tubercles. Pleon with several median tubercles. Pleotelsonic dome bearing many scattered, low, smooth tubercles and raised antero-median bulge; apex with deep ventral groove.

Antennular peduncle articles 1 and 2 sculptured; flagellum 13-articled (not 11-articled, cf. Baker, 1908: 150), extending to level of pereonite 1. Antenna 2.5 times length of antennule; flagellum 13-articled (not 11-articled, cf. Baker, 1908: 151). Epistome broader than long with transverse ridge. Pereopod 1 propodus lacking inferior conical extension. Pleopod 2 with appendix masculina 1.3 times length of endopod, straight, proximal half slightly broader than distal half, distal half with margins sub-parallel; apex rounded. Uropodal endopod not reaching level of pleotelsonic apex; exopod lanceolate, dorsally carinate, slightly shorter than endopod.

Remarks

In 1929 Baker described an ovigerous female specimen of *M. lacertosa* (1929: 58, 61, pl. 1, figs 9-11). He stated that the female had the antennae less strongly developed than the male, and that the dorsal margin of the apical pleotelsonic notch was more extended. *M. lacertosa* is known only from the above three specimens and the collection details for the female are not known.

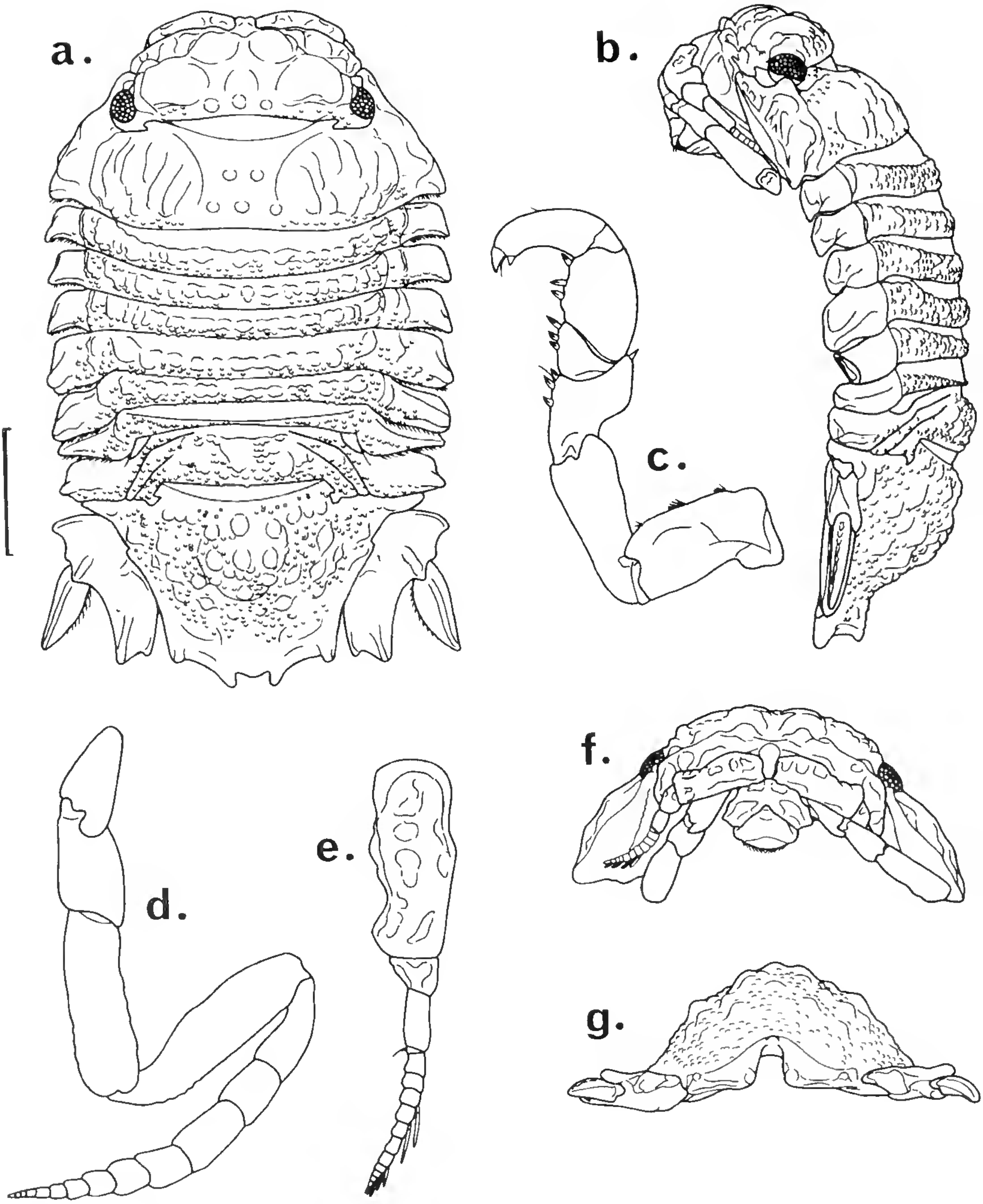

Figure 4 *Moruloidea lacertosa* Baker. Adult male (holotype), 5.17 mm; (a) dorsal; (b) lateral; (c) pereopod 1; (d) antenna; (e) antennule; (f) anterior, ventral; (g) pleotelson and uropods, posterior. Scale line represents 1 mm.

Moruloidea tumida sp. nov.

Figure 5

Holotype

Adult male, 6.9 mm. Western Australian Museum Reg. No. 69-80. Coll. 13.iii.1957 from Bathhurst Point, Rottnest Island, Western Australia (32°01'S, 115°28'E).

Paratypes

From type locality, collection details as for holotype. 1 non-ovigerous female (Western Australian Museum Reg. No. 258-82); coll. L. Glauert, 1 ovigerous female (Western Australian Museum Reg. No. 259-82).

Description

Adult Male

Cephalosome covered with prominent hemispherical protrusions. Pereonite 1 longer than succeeding pereonites, with lateral margins expanded, bilobed. Pereonites 1 to 5 each with transverse row of hemispherical tubercles. Coxal plates of pereonite 5 sub-elliptical, keeled. Pleon with anterior segment visible across mid-line; posterior segment bearing large median conical tubercle and two smaller rounded tubercles. Pleotelson with two conical projections in mid-line, and one prominent tubercle each side of these; posterior region of dome with several smaller tubercles. Pleotelsonic apex broadly truncate with triangular median extension; in posterior view, margin sinuous with ventral median groove.

Antennular peduncle article 1 weakly sculptured; 11-articled flagellum extending to level of pereonite 1. Antennal peduncle longer than entire antennule; 13-articled flagellum extending to level of pereonite 7 when antenna fully extended. Epistome broader than long with a transverse ridge; apex acute. Mouthparts not dissected (see non-ovigerous female). Pereopod 1 extremely robust; propodus with pronounced, conical, inferior extension; dactylus flexed inferiorly giving prehensile effect. Pereopods 2 to 7 slender, unmodified. Penes each twice as long as broad. Pleopod 1 basis with three medial coupling hooks. Pleopod 2 with appendix masculina 1.25 times length of endopod. Pleopod 3 exopod with complete, oblique, sub-terminal articulation. Exopods of pleopods 4 and 5 each with complete sub-terminal articulation. Uropodal endopod not reaching level of pleotelsonic apex; exopod half length of endopod, sub-elliptical, with short terminal extension.

Ovigerous Female

Cephalosome weakly bilobed. Pereon lacking obvious tuberculation; brood visible through thin cuticle behind cephalosome. Pleon with three low transverse tubercles, central being largest. Pleotelson with smooth median protuberance and weaker protuberance either side of this.

Non-ovigerous Female

Dorsal tuberculation as in adult male. Antennal peduncle article 5 not dilated or reflexed. Mandibles unmodified; incisor processes smoothly rounded; lacinia mobilis of left mandible capable of folding flat. Maxillule and maxilla of usual sphaeromatid form but inner lobe of maxilla narrow and more apically acute than usual in this family. Maxillipedal palp articles 2 to 4 bearing short superior setae.

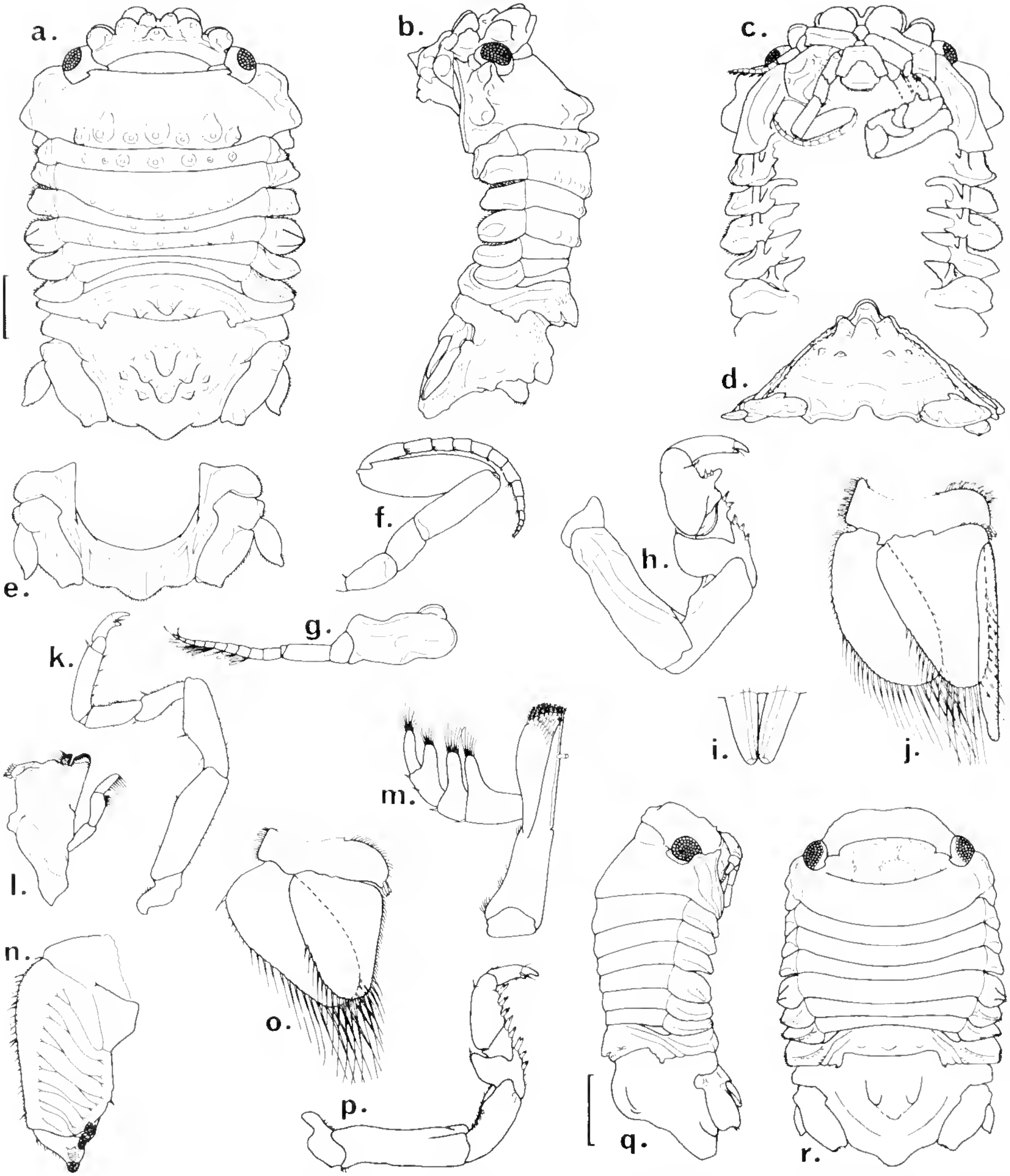

Figure 5 *Moruloidea tumida* sp. nov. Adult male (holotype), 6.9 mm; (a) dorsal; (b) lateral; (c) ventral (anterior and lateral regions); (d) pleotelson and uropods, posterior; (e) pleotelson and uropods, ventral; (f) antenna; (g) antennule; (h) pereopod 1; (i) penes; (j) pleopod 2; (k) pereopod 2; (l) left mandible; (n) pleopod 5, exopod; (o) pleopod 1. Non-ovigerous female (paratype); (m) maxilliped; (p) pereopod 1. Ovigerous female (paratype), 5.06 mm; (q) lateral; (r) dorsal. Scale line represents 1 mm in each case.

Remarks

The male and non-ovigerous female specimens of *M. tumida* sp. nov. can be distinguished from specimens of *M. darwinii* and *M. tasmaniae* by being dorsally tuberculate, not smooth, and from *M. lacertosa* by having prominent protuberances on the cephalosome, fewer and larger tubercles on the pleotelson, and by having an inferior conical tubercle on the propodus of pereopod 1 (in the adult male).

The ovigerous female of *M. tumida* (which is almost smooth) can be separated from *M. tasmaniae* by having the apex of the uropodal endopod emarginate, not rounded, and from *M. darwinii* by having three low elevations on each of the pleon and pleotelson, not one central elevation.

Moruloidea tumida is known only from the type locality, and no habitat details are known.

Etymology

Moruloidea + latin tumida, i.e. swollen.

Genus *Pseudosphaeroma* Chilton, 1909

Pseudosphaeroma Chilton, 1909: 653, 654; – Nierstrasz, 1931: 211; – Monod, 1931b: 67, 70-78; – Hurley and Jansen, 1977: 67; – Poore, 1981: 346.
Paradynamenopsis Menzies, 1962: 144; – Carvacho, 1975: 225-227; – Poore, 1981: 346.

Type Species

Pseudosphaeroma campbellense Chilton, 1909 (New Zealand, S.E. Australia – see below).

Other Species

Pseudosphaeroma lundae (Menzies, 1962) (Chile)
Pseudosphaeroma tuberculatum (Sivertsen and Holthuis, 1980), comb. nov. (Tristan da Cunha).

Diagnosis

Eubranchiate. Antennular peduncle article 1 not extended anteriorly as plate. Both sexes with pereon and pleon lacking dorsal processes. Pleonal posterior margin bearing two curved parallel sutures at each side. Both sexes with both uropodal rami lamellar. Pleotelsonic apex entire, upturned. Maxillipedal palp articles 2 to 4 bearing low setigerous lobes. Pleopod 5 exopod with apical toothed boss, extended sub-apical boss, and medial boss. Branchial folds on rami of pleopods 4 and 5 few in number, not covering entire ramal surfaces. Sexual dimorphism not pronounced.

Adult Male

Penes separate, broad, with semi-circular tips. Appendix masculina arising from medio-proximal angle of endopod of pleopod 2 and extending beyond ramal apex, dilating distally. Dorsal tuberculation more pronounced than that of female. Pereopods with inferior pads of fine setae.

Ovigerous Female

Mouthparts not metamorphosed. Brood pouch formed from three pairs of oostegites arising from pereonites 2 to 4 and overlapping well in mid-line. Oostegites increasing in size posteriorly. Brood not housed in marsupium thus formed, but in four pairs of internal pouches. Ventral pockets absent. Pereopods lacking inferior pads of setae.

Remarks

Cassidinopsis tuberculata Sivertsen and Holthuis is actually a species of *Pseudosphaeroma* (personal observation of type specimens). Of the additional species currently placed in *Pseudosphaeroma, P. barnardi* Monod, 1931 (from Africa) differs from species of *Pseudosphaeroma, sensu stricto* in not having the pleotelsonic apex deflected dorsally, in having the uropodal exopod considerably shorter than the endopod, in having the oostegites of the ovigerous female not reaching the mid-line, and (perhaps less importantly) in lacking dorsal tuberculation. *P. barnardi* cannot be retained in the genus *Pseudosphaeroma,* but its correct generic placement is unknown. *Pseudosphaeroma jakobii* Loyola e Silva, 1959 differs from species of *Pseudosphaeroma, sensu stricto* in not having the pleotelsonic apex deflected dorsally, in having the uropodal exopod considerably shorter than the endopod, and in having the ovigerous female lacking oostegites. This species cannot be retained in the genus *Pseudosphaeroma. P. jakobii* (from Brazil) appears to be closely related to '*Cassidinidea*' *tuberculata* Richardson, 1912 (from the east coast of Mexico) and '*Exosphaeroma*' *platense* Giambiagi, 1922 (from Argentina), and a new genus will probably be needed to house these three eastern American species. *Pseudosphaeroma callidum* Hurley and Jansen, 1977 (from New Zealand) differs from species of *Pseudosphaeroma* in not having the apex of the pleotelson deflected dorsally, in having the exopod of the uropod medially serrate and laterally excavate, in not having the tergum of pereonite 7 reaching the lateral margins of the body in dorsal view, and (perhaps less importantly) in lacking dorsal pleotelsonic tuberculation. *P. callidum* cannot be retained in the genus *Pseudosphaeroma,* but its correct generic placement is unknown.

Geographically, *Pseudosphaeroma* is known from New Zealand, Australia, Chile, and the Tristan da Cunha archipelago in the South Atlantic.

Pseudosphaeroma campbellense Chilton, 1909

Figure 6

Pseudosphaeroma campbellensis Chilton, 1909: 654-657; – Stephensen, 1927: 368; – Monod, 1931a: 25; – Hurley, 1961: 270, 271; – Jansen, 1971: 270; – Hurley and Jansen, 1977: 67-69; – Poore, 1981: 346.
Pseudosphaeroma campbellense – Nierstrasz, 1931: 211; – Monod, 1931b: 67, 72-75, 79, 80.

Material Examined

Swan Bay, Port Phillip Bay, Victoria (38°14'S, 144°39'E); pier of the west bank; among barnacles on pier pile; intertidal: 10 adult males, 6 ovigerous females, 4 non-ovigerous females, 5 immature specimens, 1 juvenile. Coll. G. Hartmann, 25.xii.1975 (Zoological Museum, University of Hamburg). Type specimens are located in the Canterbury Museum, New Zealand.

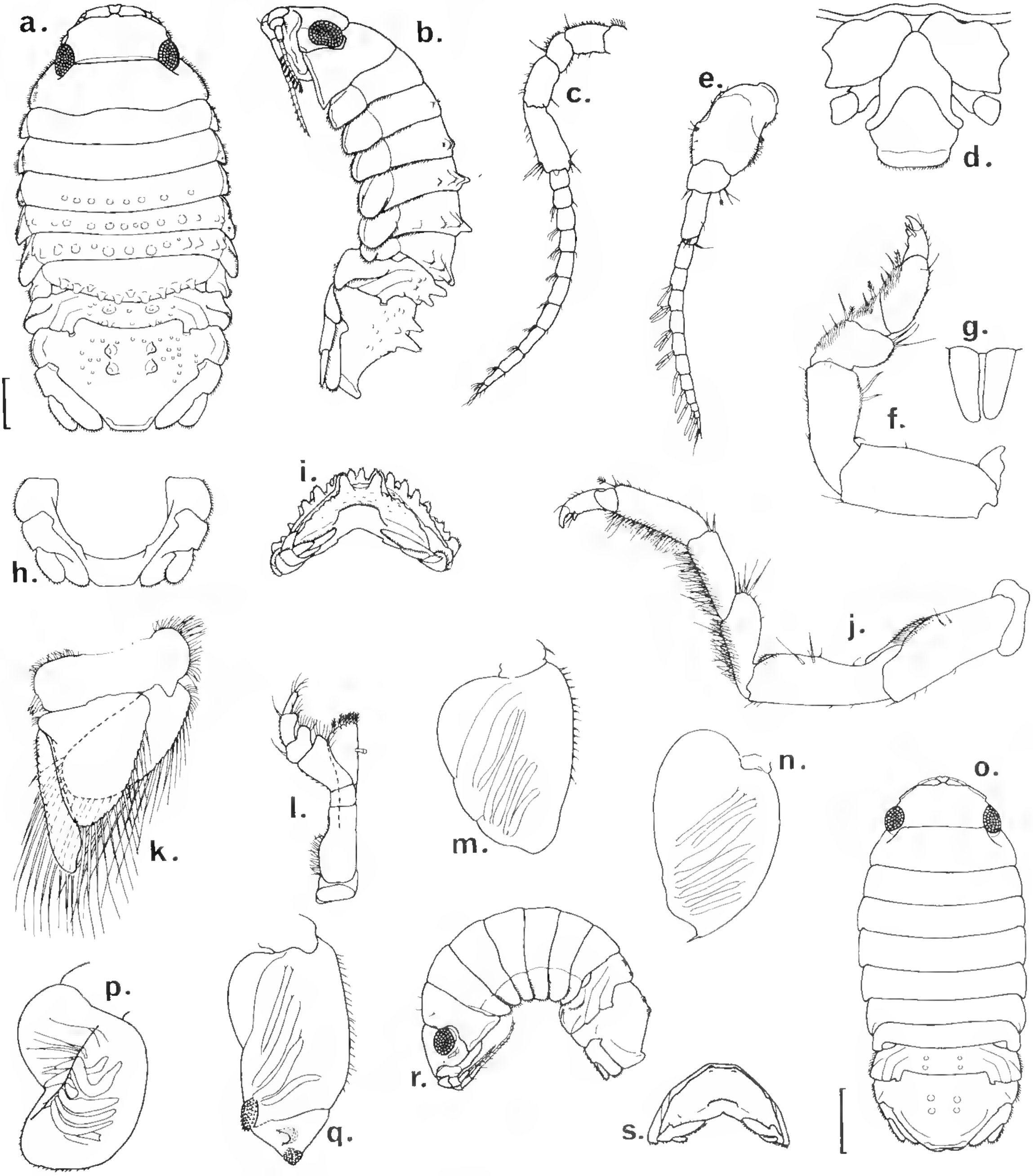

Figure 6 *Pseudosphaeroma campbellense* Chilton. Adult male, 8.25 mm; (a) dorsal; (b) lateral; (c) antenna; (d) epistome and labrum, bases of antennae, and anterior margin of cephalosome, ventral; (e) antennule; (f) pereopod 1; (g) penes; (h) pleotelson and uropods, ventral; (i) pleotelson and uropods, posterior; (j) pereopod 2; (k) pleopod 2; (l) maxilliped; (m) pleopod 4, exopod; (n) pleopod 4, endopod; (p) pleopod 5, endopod; (q) pleopod 5, exopod. Ovigerous female, 5.52 mm; (o) dorsal; (r) lateral; (s) pleotelson and uropods, posterior. Scale line represents 1 mm in each case.

Description

Adult Male

Pereonites 4 to 7 each with one transverse row of tubercles. Pleon with scattered small tubercles and two extended tubercles each side of mid-line. Pleotelson with scattered small tubercles and two extended tubercles each side of anterior mid-line.

Antennule with 12-articled flagellum extending to level of pereonite 1. Antenna with 11-articled flagellum extending to level of pereonite 2. Epistome lambdoid; apex rounded. Mouthparts unmodified. Pereopods moderately robust; inferior margins of merus, carpus and propodus bearing mats of long fine setae. Penes each three times as long as broad with semi-circular tip. Pleopod 1 basis with three medial coupling hooks; elliptical exopod extending just beyond sub-triangular endopod. Pleopod 2 with appendix masculina 1.3 times length of endopod, clavate, flattened, with lateral sub-terminal emargination. Pleopod 3 exopod with complete sub-terminal articulation. Pleopod 5 exopod with sub-terminal articulation extending from lateral margin almost to medial margin. Uropodal rami with apices rounded; endopod just longer than exopod, extending to level of pleotelsonic apex.

Ovigerous Female

Dorsal surface of cephalosome and pereon smooth. Pleon and pleotelson each with two very low tubercles each side of mid-line. Apical upturning of pleotelson less pronounced than in adult male.

Non-ovigerous Female

As above but lacking brood pouch. Oostegites present as rudimentary 'buds.'

Remarks

The name *Sphaeroma* is neuter, hence the name of this species should bear the neuter termination '-ense' not the masculine or feminine form '-ensis.'

See Discussion for remarks on distribution.

Genus *Amphoroidella* Baker, 1908

'*Amphoroidella*, new sub-genus of *Amphoroidea*' Baker, 1908: 148.
Amphoroidella – Hale, 1929: 292; – Nierstrasz, 1931: 214; Iverson, 1982: 249, 250.
Amphoridella Buss and Iverson, 1981: 2. (*lapsus calami*).

Type Species

Amphoroidea (Amphoroidella) elliptica Baker, 1908 (South Australia).

Diagnosis

Eubranchiate. Antennular peduncle articles 1 and 2 extended anteriorly as plates. Cephalosome not participating in outline of body; antennular peduncle article 2 juxtaposed to pereonite 1. Both sexes with pereon and pleon lacking dorsal processes. Pleon with posterior margin bearing one curved suture at each side. Both sexes with uropodal rami lamellar; exopod reduced, housed in indentation on lateral margin of fused basis-endopod. Pleotelsonic apex entire, truncate, lacking marked ventral groove. Maxillipedal palp articles 2 to 4 bearing pronounced setigerous lobes. Pleopod 5 exopod with two low apical, toothed bosses and low medial boss. Sexual dimorphism not pronounced.

Adult Male

Smaller than ovigerous female. Appendix masculina arising from medio-proximal angle of endopod of pleopod 2 and extending just beyond ramal apex.

Ovigerous Female

Mouthparts not metamorphosed. Brood pouch formed from three pairs of oostegites arising from pereonites 2 to 4 and overlapping well in mid-line. Posteriorly pouch formed from large anteriorly directed pocket with bilobed lip opening between fourth pereopods. Brood not held in marsupium thus formed, but in internal pouches (number not currently known).

Remarks

Since its foundation *Amphoroidella* has been treated as a full genus (see Discussion), but no diagnosis has ever been provided. The characters possessed by *Amphoroidea (Amphoroidella) elliptica* do appear to warrant separation of this species as a distinct genus, and *Amphoroidella* is here formally raised to this level.

Amphoroidella differs from *Amphoroidea* in having the second article of the antennular peduncle extended anteriorly as a plate; in not having the cephalosome participating in the outline of the body; in having the first segment of the pleon inobvious; and in having a reduced uropodal exopod. In dorsal view, specimens of *Amphoroidella* bear some resemblance to specimens of the genus *Artopoles* Barnard (from Africa), but *Artopoles* has the epistome extended anteriorly; pereonite 7 not reaching the lateral margins of the body in dorsal view; the uropodal exopods more reduced; and the pleotelsonic apex bearing a very short median incision. (*Artopoles* is currently housed in the platybranchiate sub-family Cassidininae. In fact, both known species, *A. natalis* Barnard and *A. capensis* Barnard, are eubranchiate (personal observation of type and additional specimens) and *Artopoles* should be transferred to the sub-family Dynameninae).

Amphoroidella contains only the type species, and is known only from South Australia.

Amphoroidella elliptica (Baker, 1908), comb. nov.

Figure 7

Amphoroidella elliptica Baker, 1908: 148-150, 161, pl. 6; – Hale, 1927: 319; – Hale, 1929: 296, 297; – Nierstrasz, 1931: 214.

Material Examined

Queenscliffe (Beare's Point), Kangaroo Island, South Australia (36°S, 137°E); on surface of living sponges; shallow water; 2 ovigerous females. Coll. Hale and Tindale, 1926 (South Australian Museum Reg. No. C825). Type specimens housed in South Australian Museum.

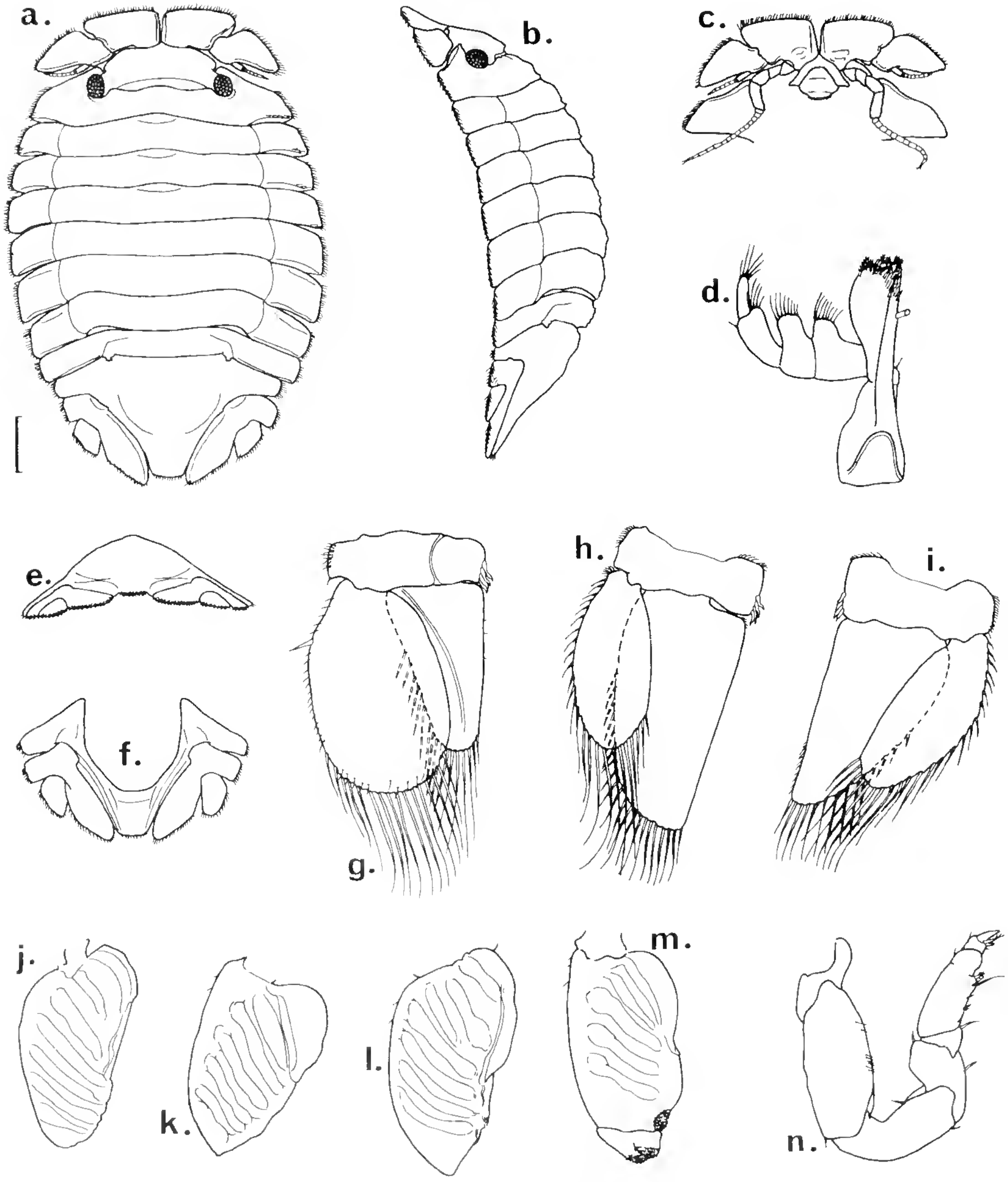

Figure 7 *Amphoroidella elliptica* (Baker), comb. nov. Ovigerous female, 7.74 mm; (a) dorsal; (b) lateral; (c) ventral, anterior; (d) maxilliped; (e) pleotelson and uropods, posterior; (f) pleotelson and uropods, ventral; (g) to (i) pleopods 1 to 3 respectively; (j) pleopod 4, endopod; (k) pleopod 4, exopod; (l) pleopod 5, endopod; (m) pleopod 5, exopod; (n) pereopod 1. Scale line represents 1 mm.

Description

Ovigerous Female

Body flattened; dorsal surface smooth, covered with layer of soft 'skin' (of unknown composition). Pleotelson not markedly domed; apex narrow, truncate.

Antennular peduncle articles 1 and 2 flattened with setose anterior margins; article 3 reduced; flagellum short. Antenna unmodified. Epistome slender, lambdoid; apex short, acute, not visible in dorsal view. Mouthparts unmodified; maxillipedal palp article 4 bearing short, superior, distal seta. Pereopods moderately robust, unmodified. Pleopod 1 basis with four medial coupling hooks; endopod with medial half slightly thickened. Pleopod 3 exopod lacking articulation. Pleopod 5 exopod with complete sub-terminal articulation. Uropodal endopod extending just beyond pleotelsonic apex; exopod set in deep notch at base of endopod.

Remarks

This species bears some resemblance to the platybranchiate sphaeromatid *Chitonopsis spatulifrons* Whitelegge (from New South Wales and South Australia) but differs in not having the epistome extended between the antennules, in having a reduced cephalosome, and in having the pleonal sutures reaching the posterior, not the lateral, margins of the tergite.

A. elliptica is known only from Gulf St Vincent and Kangaroo Island, South Australia.

Genus *Platycerceis* Baker, 1926

'*Platycerceis*'..:n. subgen.' Baker, 1926: 272.
Platycerceis – Hale, 1929: 293, 303; – Iverson, 1982: 249, 250.
Platycirceis Nierstrasz, 1931: 217. (unjustified emendation).

Type Species

Platycerceis hyalina Baker, 1926 (south and west Australia).

Diagnosis

Eubranchiate. Antennular peduncle article 1 not extended anteriorly as plate. Anterior margin of cephalosome narrowly rounded, dorso-ventrally flattened, extended anteriorly to cover proximal regions of antennules and antennae. Median rostral process directed postero-ventrally; rostral process and epistome never visible in dorsal view. Body extremely flattened; coxal plates directed laterally and extended as slender, separate, acute processes. Pereon and pleon lacking dorsal processes. Pleon with lateral margins extended as acute processes; dorsal surface bearing two long suture lines at each side, one reaching postero-lateral angle, other reaching posterior margin. Antennular peduncle article 1 bearing acute antero-distal and postero-distal processes. Pleopod 5 exopod bearing two sub-apical, extended, toothed bosses, one on each side of ramus; medial margin, at junction of proximal and distal articles, only weakly toothed, lacking prominent bosses. Uropodal rami extended, styliform, sub-equal.

Adult Male

Penes separate, short, with semi-circular tips. Appendix masculina long, arising from medial margin of endopod of pleopod 2, extending to pleotelsonic apex. Maxillipedal palp broad; articles 2 to 4 with pronounced setigerous lobes.

Ovigerous Female

Not known.

Remarks

The current status of *Platycerceis* is not clear (see Discussion). It is formally recognized here as a full genus. *Platycerceis* differs from the most closely related genus, *Cerceis* Milne Edwards, in the extreme flattening of the body, the extended separate coxal plates, the narrow styliform uropods, and the greater length of the appendix masculina. This genus is known only from the type species and ovigerous females have not been collected.

Platycerceis hyalina Baker, 1926

Figure 8

'*Platycerceis hyalina*, n. subgen. and sp.' Baker, 1926: 272, 273, 279, pl. 52.
Platycerceis hyalina Hale, 1929: 303; Iverson, 1982: 250.
Platycirceis hyalina Nierstrasz, 1931: 217 (unjustified emendation)

Material Examined

Cockburn Sound, Perth, Western Australia (32°10'S, 115°40'E); dredged offshore, 3 miles west of B.H.P. 1 adult male. Coll. P. Cawthorn, 'Lancelin,' 30.vii.1961. (Western Australian Museum Reg. No. 64-80). Type specimens are located in the South Australian Museum.

Description

Adult Male

Each pereonal tergite with posterior margin bearing row of short setae. Pleon and pleotelson smooth, lacking dorsal setae. Pleotelson flat, not domed; apex with narrow acute process each side of deep anteriorly rounded notch.

Antennular peduncle article 1 with acute distal processes enclosing proximal region of article 2; 21-articled flagellum reaching level of pereonite 4. Antenna with 18-articled flagellum reaching pereonite 4. Epistome lambdoid. Mouthparts unmodified. Pereopods robust, lacking setae; propodi expanded with rows of stout inferior spines. Penes each twice as long as broad with semi-circular tip. Pleopod 1 basis with three medial coupling hooks. Pleopod 2 exopod bearing 15 marginal 'teeth.' Appendix masculina tapering distally, folded along most of length forming medially open channel; apex acute. Pleopod 3 exopod with complete sub-terminal articulation. Pleopod 4 exopod with small, lateral, marginal toothed boss. Pleopod 5 exopod with complete, but weak, sub-terminal articulation. Uropodal rami extending well beyond pleotelsonic apex; both rami with dorsal and ventral longitudinal ridges; exopod with lateral margin serrate.

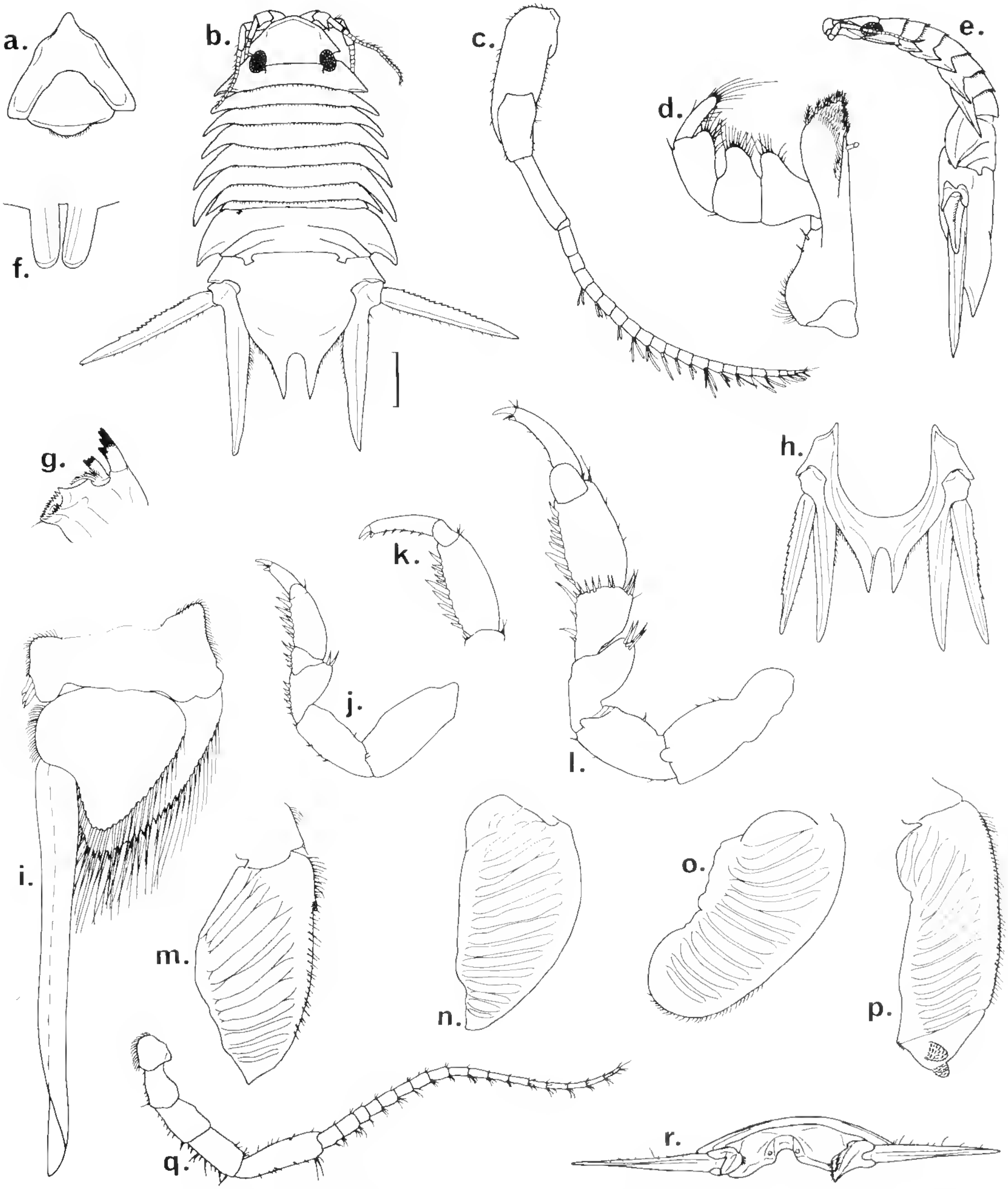

Figure 8 *Platycerceis hyalina* Baker. Adult male, 7.01 mm; (a) epistome and labrum; (b) dorsal; (c) antennule; (d) maxilliped; (e) lateral; (f) penes; (g) left mandible; (h) pleotelson and uropods, ventral; (i) pleopod 2; (j) pereopod 1; (k) pereopod 2, propodus and dactylus; (l) pereopod 4; (m) pleopod 4, exopod; (n) pleopod 4, endopod, (o) pleopod 5, endopod; (p) pleopod 5, exopod; (q) antenna; (r) pleotelson and uropods, posterior. Scale line represents 1 mm.

Remarks

This species has only been recorded previously by Baker from Gulf St Vincent, South Australia. *P. hyalina* bears a strong resemblance in dorsal view to *Platynympha longicaudata* but lacks a median extension in the pleotelsonic notch, and is more flattened.

Discussion

The genus *Waiteolana* is currently housed in the subfamily Cassidininae. The discovery of *W. gibbera* sp. nov. and the associated ability to examine a number of specimens has shown that although the folding of the endopods of pleopods 4 and 5 is not strongly pronounced, it is clearly present, especially in unmounted pleopods. When pleopods are mounted as microslide preparations the folds may be less obvious. Re-examination of the mounted pleopods from the holotype of *W. rugosa* has shown that folds are present, not absent as previously reported (Baker, 1926: 276; Holdich and Harrison, 1981a: 635). This genus must be transferred to the sub-family Sphaeromatinae.

W. tuberculata Kussakin is known from only one specimen. Kussakin (1967) was not confident that this specimen belonged in the genus *Waiteolana*, and the incomplete original description does not allow detailed comparisons with the other species. *W. tuberculata* must be redescribed before its status can be clarified.

The history of the genus *Moruloidea* is rather involved. Baker (1908) established this genus to house his new species *M. lacertosa*. In 1914 Stebbing erected the genus *Euvallentinia* for the species *Cymodoce darwinii* Cunningham (from S. America) (For a more detailed discussion of the history of *Euvallentinia* see Loyola e Silva, 1974: 19-22). In 1926 Baker described a new species which he placed in the genus *Cassidinopsis* Hansen as *C. tasmaniae*. Baker appended his description of this species with the remark, 'In 1908 I established a genus, *Moruloidea*, knowing very little of its affinity. I now believe it to be very close to the present genus,' (*Cassidinopsis*) 'and may have to be united to it in the future.' Nierstrasz (1931: 218) presumably acted on this suggestion when he included *M. lacertosa* in the genus *Cassidinopsis*.

Examination by the present author of specimens of *Euvallentinia darwinii* and type specimens of *Moruloidea lacertosa* and *Cassidinopsis tasmaniae* has shown that these three species appear to be congeneric. The only major difference between *M. lacertosa* and *E. darwinii* is that *M. lacertosa* is dorsally ornamented while *E. darwinii* is smooth. As dorsal tuberculation is known to vary between species in other sphaeromatid genera (e.g. *Sphaeroma* Latreille, *Ischyromene* Racovitza) the present author does not consider this difference sufficient to warrant separate generic status, and *Euvallentinia* is included here as a junior synonym of *Moruloidea*.

As *Cassidinopsis tasmaniae* is in fact a species of *Moruloidea*, it is not surprising that Baker – presumably assuming this species to be representative of *Cassidinopsis* – considered *Cassidinopsis* and *Moruloidea* to be so closely related. Examination of specimens of *Cassidinopsis emarginata* (Guérin-Méneville) has shown that *Cassidinopsis* is distinct from *Moruloidea* but is closely related to the genus *Amphoroidea* Milne Edwards.

The genus *Pseudosphaeroma* was originally described as eubranchiate, but was transferred to the hemibranchiate sub-family by Monod (1931b). Monod's action was based partly on the reduced pleopodal folding shown by *Pseudosphaeroma* specimens (compared with specimens of other eubranchiate genera), and partly on an analysis of non-pleopodal characters. Although pleopodal folds are reduced in number in *Pseudosphaeroma*, both rami of both pleopods 4 and 5 bear folds and this genus is clearly eubranchiate. Monod's opinions are rejected here and *Pseudosphaeroma* is transferred to the subfamily Dynameninae.

The three known species of *Pseudosphaeroma* strongly resemble one another, but as these species were described in different genera, a detailed comparison has never been made. The only differences between the three species appear to be in the form of the appendices masculinae and the dorsal tuberculation. However, Hurley and Jansen (1977: 68, 69) have stated that specimens of *P. campbellense* from New Zealand show variation in both these characters, this variation apparently being related to geographical location. The differences between *P. campbellense*, *P. lundae* and *P. tuberculatum* are so slight that there is possibly only one species of *Pseudosphaeroma*, extending around the Southern Hemisphere and varying with geographical location. However, until extensive comparative work is carried out to test this theory, it would be unwise to synonymise the three species. Such comparative work will also be required before a reliable character for separating these species (if any exist) can be found. The appendix masculina shows greater variation of form amongst the New Zealand specimens of *P. campbellense* than between the known species (Hurley and Jansen 1977: Fig. 62) and this structure must be considered unreliable for species separation. Despite inter-specific variation in the prominence of the dorsal tuberculation, no previously described specimen has the tubercles as pronounced as the present Australian material. However, as tuberculation is known to vary in *P. campbellense*, it is considered here that the greater tuberculation of the Australian material is not sufficient reason for designating these specimens as a separate species or sub-species. Poore (1981) illustrated specimens of *P. campbellense* from the Snares Islands which appear to show tuberculation intermediate between that of the Australian material and Hurley and Jansen's New Zealand material. It is possible that the Port Phillip specimens form the western end of a cline linking New Zealand and Australia. Although New Zealand and Australia share few species of peracarid crustaceans, at least one other sphaeromatid species, '*Cerceis*' *trispinosa* (Haswell), is found in both south-east Australia and New Zealand (recorded from New Zealand as *Cymodoce granulata* Miers).

Alternatively, the Australian population of *Pseudosphaeroma* may have been transported to Port Phillip by shipping. A number of sphaeromatid species are believed to have been dispersed in this way (e.g. *Sphaeroma walkeri* Stebbing, *Paradella dianae* (Menzies)) (Carlton and Iverson 1981; Harrison and Holdich 1982a).

The genera *Amphoroidella* and *Platycerceis* were both originally described as subgenera, but subsequent authors have treated them as full genera without formally raising them to this level or providing any generic diagnoses.

Baker clearly erected *Amphoroidella* as a subgenus of *Amphoroidea*, but he described the type species as '*Amphoroidella elliptica*' and later referred to 'this genus' (implying

Amphoroidella rather than *Amphoroidea*) (Baker 1908: 148, 150). Although subsequent authors have treated *Amphoroidella* as a full genus, no reasons were given for the apparent elevation. Iverson (1982: 250) stated that Hale (1929) 'raised the name to full generic status without comment.' Hale (1929: 292) did separate *Amphoroidella* and *Amphoroidea* in his key to the genera, saying that the second article of the antennular peduncle was expanded in *Amphoroidella* but not in *Amphoroidea*, but this cannot be considered a generic diagnosis. It seems likely that Hale was not raising the status of *Amphoroidella*, but was merely copying Baker and using the binomen *Amphoroidella elliptica*. While doubt exists, and in the absence of a diagnosis, it seems wise to assume that *Amphoroidella* has never been raised to full generic rank.

When Baker described the subgenus *Platycerceis* he did not indicate to which genus it belonged. It was introduced following his new genus *Exocerceis* Baker, but does not show the characteristics of *Exocerceis* (Baker 1926: 271, 272). Baker may have formed *Platycerceis* as a subgenus of *Cerceis*, but in describing the 'teeth' on the exopod of pleopod 1 he stated 'as in *Cerceis*'! In the absence of a positive indication by Baker, *Platycerceis* has been treated as a full genus, and Iverson (1982: 250) suggested that Baker may never have intended it to be a subgenus. Iverson also stated that Hale (1929) raised *Platycerceis* to full generic rank without comment. Hale did say for *Platycerceis*; 'Distinguished from *Cerceis* by the more flattened body and the outstanding side-plates of the thorax' (1929: 303), but, as with *Amphoroidella*, Hale was probably following Baker's usage rather than actively raising the status of the taxon. To avoid further confusion, *Platycerceis* is here formally recognised as a full genus and a diagnosis is provided. The type species has been cited using the only binomen available, *Platycerceis hyalina*.

Postscript

Since going to press the author has become aware of two further publications relevant to the above work. Schultz (1978) described a new species, *Cassidinopsis tuberculata*, from the South Atlantic. This name is a senior homonym of *C. tuberculata* Sivertsen and Holthuis. Therefore, if *Pseudosphaeroma tuberculatum* proves to be a distinct species (see Discussion above) it will require a replacement name. *C. tuberculata* Schultz (based on one specimen) appears to be the female of a species of *Moruloidea*.

Kussakin and Vasina (1982) described two new species in the genus *Euvallentinia*, *E. fraudatrix* and *E. ornata*. Each species was founded on one female specimen and both were collected at Kerguelen Island. Unfortunately, without examining these holotypes the present author is unable to comment on their taxonomic status.

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A New *Lerista* (Lacertilia: Scincidae) from Western Australia

G.M. Storr*

Abstract

A new skink, *Lerista simillima*, is described from the far north of Western Australia. It is a member of the *L. bipes* group and very close to *L. labialis*.

Introduction

A grant from Mr and Mrs W.H. Butler enabled the Museum to send two amateur herpetologists to the Kimberley Division in February 1984. Reptiles and amphibians were collected between Sandfire and Wyndham, especial attention being paid to fossorial snakes and lizards.

Among the latter were 45 members of the *Lerista bipes* group (Storr 1972), viz. two specimens of *L. ips* Storr, 1980 from 7 km E and 19 km NE Sandfire; 36 specimens of *L. griffini* Storr, 1982 from 1 km E and 10-12 km NE Kununurra, near Broome, 38 km ESE Broome and 13 km E Anna Plains; one specimen of *L. bipes* (Fischer, 1882) from 7 km E Sandfire; two specimens of *L. greeri* Storr, 1982 from 3 km SW Debesa; and four specimens of a new species which is now described.

Lerista simillima sp. nov.

Figure 1

Holotype

R87106 in the Western Australian Museum. Collected by G. Harold and D. Mead-Hunter on 4 February 1984 at 6 km WNW Fitzroy Crossing, Western Australia, in 18°11'S, 125°31'E.

Paratypes

Kimberley Division (W.A.)

4 km SE Ellendale HS (R87094-6).

Diagnosis

A member of the *Lerista bipes* group with movable eyelids, two toes, no trace of forelimbs, two supraoculars and no supraciliaries; very like *L. labialis* Storr, 1972 but more slender, less reddish and having both supraoculars in contact with frontal, the second slightly larger than the first (in *L. labialis* the second supraocular is much the smaller and not in contact with frontal). Distinguishable from *L. greeri* and *L. bipes* by absence of supraciliaries, and from *L. griffini* by presence of a preocular and high (rather than low, flat) second loreal.

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Description

Snout-vent length (mm), 42-54. Length of appendages (% SVL): tail 86 (N 1); hindleg 16-19.

Nasals narrowly separated (N 2) or in point contact (2). Prefrontal fused to second loreal (as in *L. labialis, L. greeri* and *L. bipes*). Nuchals 2. Frontoparietals and interparietal fused. Supraoculars 2, both in contact with frontal, second slightly larger than first. No supraciliaries. Loreals 2, second high with acute apex. Preocular present. Temporals 3; upper secondary largest or subequal to primary, lower secondary much the smallest. Upper labials 6. Midbody scale rows 20 (N 3) or 21(1). Lamellae under longer toe 10.

Upper surfaces pale brown. Head sparsely to moderately spotted with dark brown. Back and tail with two paravertebral lines of small dark brown spots. Wide blackish-brown upper lateral stripe from nostril to end of tail. Ventral and lower lateral surfaces whitish.

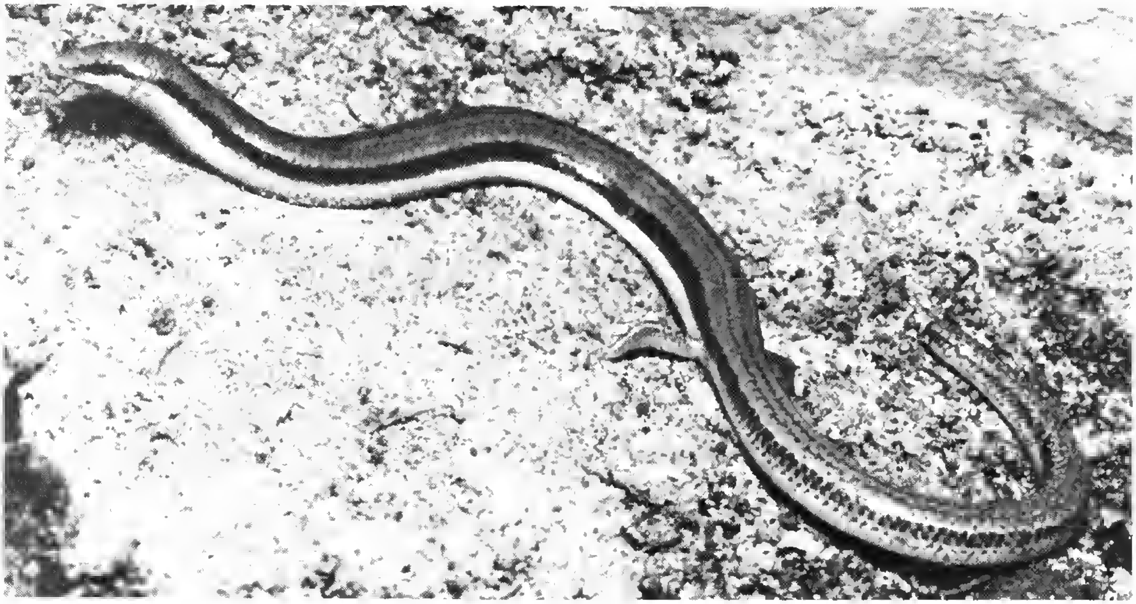

Figure 1 A paratype of *Lerista simillima* from Ellendale, photographed in life by G. Harold.

Distribution

Only known from two localities in semi-arid south Kimberley; at both sites the soil is red sandy loam and the vegetation pindan. See Figure 2.

Derivation of Name

From Latin *simillimus* (very similar).

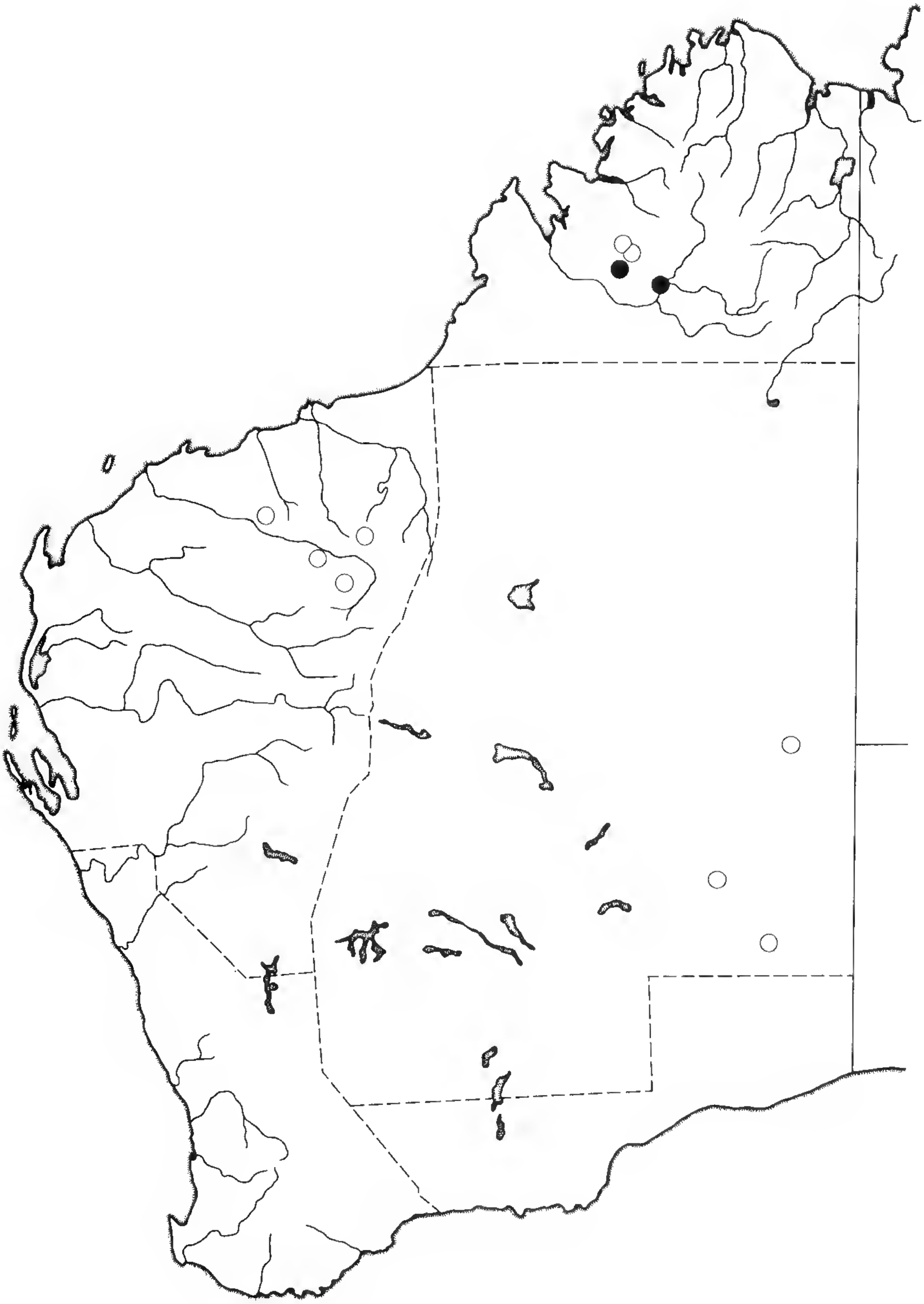

Figure 2 Map of Western Australia showing location of specimens of *Lerista simillima* (solid circles) and *L. labialis* (hollow circles).

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Intergradation between Lemon-breasted Flycatcher *Microeca flavigaster* Gould and Brown-tailed Flycatcher *Microeca tormenti* Mathews in Cambridge Gulf, Western Australia

R.E. Johnstone*

Abstract

The mangroves of Cambridge Gulf, Western Australia, are inhabited by flycatchers intermediate between *Microeca flavigaster* and *M. tormenti*. In recent times these have been treated as separate species because of fairly pronounced differences in coloration and to a lesser extent habitat preferences. *M. flavigaster* occurs in a wide variety of woodlands and forests, including mangroves, whereas *M. tormenti* is confined to mangroves. It is now shown that these birds are conspecific.

Introduction

Until recently there were only three records of *Microeca flavigaster* for Western Australia. Mr C.F.H. Jenkins collected a specimen and observed several pairs along the banks of the Ord River at Ivanhoe Station in 1944. Mr I.C. Carnaby observed one or two pairs in semi-jungle on the lower Ord River (about 60 km SE of Wyndham) in 1965 and 1966. Mr R.P. Jaensch saw two birds with bright lemon bellies in a tree thicket at Parry Creek (about 23 km SE of Wyndham) on 16 March 1983.

On the other hand *M. tormenti* was known from many specimens and observations throughout its range which Storr (1980) gave as north-west and west coasts, from Napier Broome Bay (Pago) south-west to Barred Creek (40 km N of Broome) also continental islands Bigge, Boongaree and Augustus (Figure 1).

The known ranges of *M. flavigaster* and *M. tormenti* were thus separated by a gap of 260 km. Because *M. tormenti* was confined to extensive blocks of mangrove forest, favouring mixed forest of *Rhizophora*, *Bruguiera*, *Avicennia* and *Aegiceras*, it was considered doubtful that it would occur east of Cape Londonderry, as the coast from there to Cape Dussejour at the western head of Cambridge Gulf is mainly rocky with only small isolated patches of mangroves. These small patches appeared unsuitable for *M. tormenti* even though it is occasionally found in lower vegetation.

Throughout its fairly extensive range *M. tormenti* underwent no geographic variation, i.e. the northeastern-most specimens showed no tendency towards *M. flavigaster*, similarly the western-most specimens of *M. flavigaster* showed no tendency towards *M. tormenti*.

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Whether *M. tormenti* was a subspecies of *M. flavigaster* or a full species, seemed likely to remain a matter of opinion. How important was the lack of yellow on the under surface of *M. tormenti*, and how important was its restricted habitat preferences?

Parker (1973) adopted the suggestion of Mayr and Serventy (1944) and Vaurie (1953) that *tormenti* and *flavigaster* should be regarded as conspecific. He also added that investigation was needed between Napier Broome Bay and Carlton Reach to see if their ranges did meet.

This enigma was resolved in October 1982 when a survey of the Cambridge Gulf mangroves was carried out by the Department of Fisheries and Wildlife and the Western Australian Museum. Six *Microeca* specimens (4♂ 2♀) collected from three different locations within the Gulf proved to be intermediate between *M. flavigaster* and *M. tormenti*.

These specimens were compared with material from the Australian National Wildlife Collection and the Western Australian Museum. The following measurements were taken: length of chord of flattened wing, length of tail (along a central rectrix), length of tarsus, length of entire culmen and width of culmen.

Morphological Variation

Descriptions are given below for *M. flavigaster* (from W.A. and N.T.), *M. tormenti* and the six Cambridge Gulf specimens (the latter starting with those having the least yellow on their under parts).

Microeca flavigaster

Head and nape dull olive-green; back, rump and wing coverts olive-green; wings greyish-brown, the outer fringe of the primaries and secondaries yellowish-white; tail coverts dull olive-green; tail brown, outer fringe of many feathers olive-green; throat white; breast yellow; sides of breast and flanks olive-grey; belly bright yellow; undertail coverts yellow; bend of wing and underwing coverts yellow.

Unfeathered parts: iris brown or dark brown; upper mandible black; lower mandible dark brown with black tip; mouth yellow; legs slate grey, black or purplish brown.

Specimens Examined: WAM A550, A551, A552, CSIRO 6362, 14766, 15912, 16302, 14105, 6367, 6287, 18811, 16015.

Microeca tormenti

Head and nape grey; back, rump and wing coverts brown tinged with olive; wings greyish-brown, the outer fringe of primaries and secondaries dull white; tail coverts greyish-brown; tail brown, outer fringe of some feathers white; throat white; breast white; sides of breast and flanks grey; belly and undertail coverts white; bend of wing and underwing coverts white tinged yellow.

Unfeathered parts: iris dark brown (5), brown (4), red-brown (2), grey-brown (1); upper mandible black or brown; lower mandible pale horn or brown with a dark tip; mouth yellow; legs black (9), brownish-black (2), dark grey (1).

Specimens Examined: WAM A14774, A14773, A11597, A14775, A15097, A15009, A15010, A12627, A12626, A14677, A14023, A14022.

Figure 1 Map of Northern Territory and Kimberley, Western Australia, showing distribution of *Microeca f. flavigaster* (hollow circles), *M. f. tormenti* (solid circles), and intermediate specimens.

Table 1 Measurements (mm) of *Microeca flavigaster* with means and sample size in parentheses.

		Wing	Culmen length	Culmen width	Tail	Tarsus
Microeca flavigaster flavigaster	♂ (N7)	72-76 (73.7)	12.0-14.0 (13.4)	5.3-5.8 (5.6)	49-53 (51.4)	14.0-15.0 (14.5)
W.A. and N.T.	♀ (N6)	67-72 (69.6)	12.5-14.0 (13.1)	5.0-5.8 (5.4)	49-51 (49.6)	13.0-15.0 (14.1)
M. flavigaster x *tormenti*	♂ (N4)	73-76 (74.2)	14.0-14.5 (14.1)	5.1-5.8 (5.6)	51-55 (52.7)	15.0-15.5(15.1)
Cambridge Gulf	♀ (N2)	72-73	14.0-14.5	5.5-5.9	51-53	14.5-15.0
M. flavigaster tormenti	♂ (N7)	74.75 (74.4)	14.0-15.0 (14.5)	5.3-5.8 (5.5)	51-56 (53.8)	14.0-18.0 (15.7)
W.A.	♀ (N4)	70-74 (71.2)	14.0-14.0 (14.0)	5.4-5.7 (5.5)	50.54 (51.7)	13.0-16.0 (15.0)

Cambridge Gulf Specimens

WAM A17645 adult female (skull fully ossified, ovary with one developing egg follicle) collected near Black Cliff Point on 12 October 1982 at outer edge of *Rhizophora* forest with some dead *Rhizophora* and *Avicennia*.

Head and nape dark grey; back brown with faint tinge of olive; rump brown tinged olive; wings greyish-brown, the outer fringe of primaries and secondaries white; tail coverts greyish-brown; tail dark brown; throat white; breast white tinged with yellow; sides of breast and flanks grey; belly white, tinged with yellow; undertail coverts white; bend of wing and underwing coverts white tinged with yellow.

Unfeathered parts; iris dark brown; upper mandible blackish-brown; lower mandible bone with blackish-brown tip; mouth yellowish; legs black.

Very like *M. tormenti*, but head darker and back and rump less olive.

WAM A17642 adult male (testes enlarged, 7 × 6 mm) collected near Black Cliff Point on 11 October 1982 at landward edge of *Rhizophora* forest.

Head and nape grey; back and wing coverts brown tinged olive; rump olive; wings greyish-brown; the outer fringe of primaries and secondaries white; tail coverts brown tinged olive; tail dark brown; throat white; breast whitish-grey; sides of breast and flanks grey tinged yellow; belly white with yellow tinge (strongest at midline); vent and undertail coverts white; bend of wing and underwing coverts white tinged with yellow.

Unfeathered parts: same as for A17645 except for brown legs.

Very like *M. tormenti* but slightly more olive on back and rump and having a yellowish tinge to breast and belly.

WAM A17796 adult male (testes 6 × 3 mm) collected 3 km south of Hardman Point on 12 October 1982 in *Rhizophora* forest.

Head and nape grey; back, rump and wing coverts olive; wings greyish-brown, the outer fringe of primaries and secondaries white; tail coverts greyish-brown; tail brown; throat white; breast white tinged yellow; sides of breast and flanks pale greyish-white tinged yellow; belly white tinged yellow; undertail coverts white with faint yellow tinge; bend of wing and underwing coverts white tinged yellow.

Unfeathered parts: same as A17645.

Fairly similar to *M. tormenti* but upper parts more olive and under parts more yellowish.

WAM A17643 adult male (testes 5.0 × 3.5 mm) collected near Black Cliff Point on 12 October 1982 in *Rhizophora* forest.

Head and nape grey; back, rump and wing coverts olive; wings greyish-brown, the outer fringe of the primaries and secondaries white; tail coverts greyish-brown; tail dark brown; throat white; breast greyish-white tinged with yellow; sides of breast and flanks greyish-white tinged yellow; belly white with strong yellow tinge; undertail coverts white tinged yellow; bend of wing and underwing coverts yellowish-white.

Unfeathered parts, similar to A17645 except for grey-brown legs.

Almost exactly intermediate.

WAM A17641 adult male (testes 6 × 3 and 5 × 3 mm) collected 7 km NNE of Mount Connection on 9 October 1982 in thicket of *Avicennia*, *Excoecaria* and *Ceriops* at edge of tidal creek.

Head and nape brownish olive; back, rump and wing coverts olive; wings greyish-brown, the outer fringe of primaries and secondaries yellowish-white; tail coverts greyish-brown;

tail dark brown; throat white; breast dull yellowish-grey, darker on sides of breast; belly pale yellow; undertail coverts yellow; bend of wing and underwing coverts yellowish-white.

Unfeathered parts as in A17645 except for grey legs.

Fairly similar to *M. flavigaster* but has less olive on head and back and less yellow on under parts.

WAM A17644 adult female collected near Black Cliff Point on 12 October 1982 on landward side of *Rhizophora* forest.

Head and nape greyish-olive; back, rump and wing coverts olive; wings greyish-brown, the outer fringe of primaries and secondaries yellowish-white; tail coverts greyish-brown; tail dark brown; throat white; breast greyish-yellow, darker on sides; belly pale yellow; undertail coverts white tinged yellow; bend of wing and underwing coverts yellowish-white.

Unfeathered parts, same as A17645.

Very like *M. flavigaster* but slightly darker on upper parts including tail and less yellow on under parts.

Discussion

The six Cambridge Gulf specimens were collected in what I consider to be typical *M. tormenti* habitat, i.e. mangrove forest with scattered dead trees. Nearly all the birds were calling from the canopy, and judging from their behaviour and gonads they were preparing to breed. Three different calls were noted: a short 'peter peter' and 'treet treet' and a longer 'pa-tree-ter' repeated three or four times. I have heard similar calls from *M. tormenti* and also a sharper 'k'chip.'

The main differences between *M. tormenti* and *M. flavigaster* are the colour of the head and nape (grey in *tormenti*, olive-green in *flavigaster*), the back and tail (more brown in *tormenti*, more olive in *flavigaster*) and breast and belly (almost pure grey and white in *tormenti*, yellow in *flavigaster*). The characters break down in the Cambridge Gulf series, the specimens showing a wide range of intermediacy, with A17645 at one end close to *M. tormenti* and A17644 at the other end close to *M. flavigaster.*

On the basis of these data, it is considered that the Brown-tailed Flycatcher should now be called *Microeca flavigaster tormenti*.

Acknowledgements

I am grateful to Dr R. Schodde (CSIRO) for the loan of specimens, and to Dr G.M. Storr for his comments on the manuscript. I am also grateful to Mr N.L. McKenzie for inviting me to his survey of the Cambridge Gulf mangroves and to Mr and Mrs W.H. Butler, whose grant to the Western Australian Museum enabled my participation in it.

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Native Mammal Remains from Wilgie Mia Aboriginal Ochre Mine: Evidence on the Pre-European Fauna of the Western Arid Zone.

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Abstract

Remains of native mammals were recovered in the course of an archaeological excavation in Wilgie Mia, an Aboriginal ochre mine in the arid upper Murchison region. Almost all the specimens were recovered from loose ochre matrix which had accumulated over approximately the last 1000 years. Most of the bones are probably the remains of owls' prey, a few may have been contributed by humans or dogs; some of the larger species may have died in the mine. The total sample represents about 100 individuals, far too small for any trends in species composition through the deposit to be detected.

Mammals identified included Pig-footed Bandicoot, *Chaeropus ecaudatus;* both species of stick-nest rat, *Leporillus apicalis* and *L. conditor;* and the Long-tailed Hopping-mouse, *Notomys longicaudatus,* all of which are now very rare or extinct in western Australia, and have been recorded from very few localities. The Shark Bay Mouse, *Pseudomys praeconis,* is also recorded from this inland site. The distributions of the species in the fossil fauna are discussed: all are known to occur in arid regions of Australia.

The fauna provides evidence on the original distributions of the mammals before they were affected by European man.

Introduction

An archaeological excavation was made in 1962 in Wilgie Mia, the Aboriginal ochre mine (Western Australian Museum site register No. P1014) in the Weld Range at latitude 26°55'S. longitude 117°42'E. (Figure 1), by a team from the Western Australian Museum under the direction of Dr I.M. Crawford. In addition to artefacts, small numbers of animal bones were recovered from many levels in the deposit.

Before about 1960 very few living mammal specimens had been collected in the upper Murchison region, which has been under pastoral exploitation since the beginning of this century. As a result, much of the native fauna disappeared without being recorded. Since the Wilgie Mia remains include the only recent mammal fossils known from the area they are important in providing evidence on the fauna present before the arrival of European man.

The bones from the deposit were sorted and identified and a rich mammal fauna, including several species not previously known from the area, was found to be represented.

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The specimens have been accessed into the vertebrate palaeontological collections of the Western Australian Museum under the catalogue numbers 73.1.15 to 73.1.252. Other specimens referred to below with numbers prefixed by M (e.g. M8709) are in the modern mammal collection of the Western Australian Museum.

Geomorphology, Climate and Vegetation

The Weld Range is a prominent feature of the upper Murchison region; it forms a watershed between the drainages flowing north into the Murchison River, and south into Lake Austin. It is about 50 km long and consists of two or three straight, steep, parallel ridges with many rock outcrops. The highest point is Gnanagooragoo Peak (formerly Mount Lulworth) which rises some 320 m above the surrounding plain. Wilgie Mia lies about 5 km south-south-west of Gnanagooragoo Peak, near the crest of a ridge on the southern side of the range (Woodward 1914).

The following account of the geology is based mainly upon Ellis (1955) and Jones (1963). The Weld Range is composed principally of greenstones, interlayered with a series of steeply dipping jaspilites. They are probably of Archaean age. The jaspilite beds are banded iron formations, in some cases including iron ore lenses. Wilgie Mia lies in one such lens where the rock consists of thin alternating bands of shale and haematite. The shale has become impregnated with iron oxide to form the red ochre. The country surrounding Weld Range consists largely of the weathering products of Archaean granite, and has very little relief.

The climate of the area is arid (Arnold 1963). Predominantly clear skies cause temperatures to fluctuate widely through both daily and seasonal cycles. In the coolest winter month (July) the mean daily maximum is about 19°C, but ground frost may occur at night; in summer daily maxima are very high, with a January mean maximum of about 37°C. Median annual rainfall is about 200 mm, and most falls between late summer and the end of winter. Sufficient effective rainfall to initiate plant growth occurs on average three times per year, most frequently in early winter. However, the rainfall is generally highly variable, which allows the perennial existence of only those plant species which can withstand periods of several years without sufficient rain to permit growth. The soils of the area are mainly stony soils and shallow red earths (Mabbutt *et al.* 1963). As a result of these climatic and soil factors the vegetation is principally tall shrubland or tall open-shrubland in which the upper storey is usually mulga (*Acacia aneura*) (Mabbutt *et al.* 1963). A low shrub storey is sometimes well developed, and annual forbs appear after rain. Some halophytic communities also occur. Early photographs (e.g. Woodward 1914: figure 39) show that originally tall shrubland extended on to the slopes of the range below Wilgie Mia.

The Site and the Crawford Excavation

The form of Wilgie Mia has been altered by European mining operations. However, its shape and size at the beginning of this century were recorded by Woodward (1914). It consisted of an open first chamber about 20 m across sloping down from the entrance lip to a wall about 14 m high. Leading off from the side of this first chamber was a larger main chamber, the ceiling of which was at a fairly constant height of about 10 m. It sloped down for about 35 m, widening to a back wall about 40 m long. In the walls of both chambers were the entrances to narrow passages made by Aborigines following veins of soft ochre. Mounds of loose material resulting from their mining had accumulated on the floors of the large chambers.

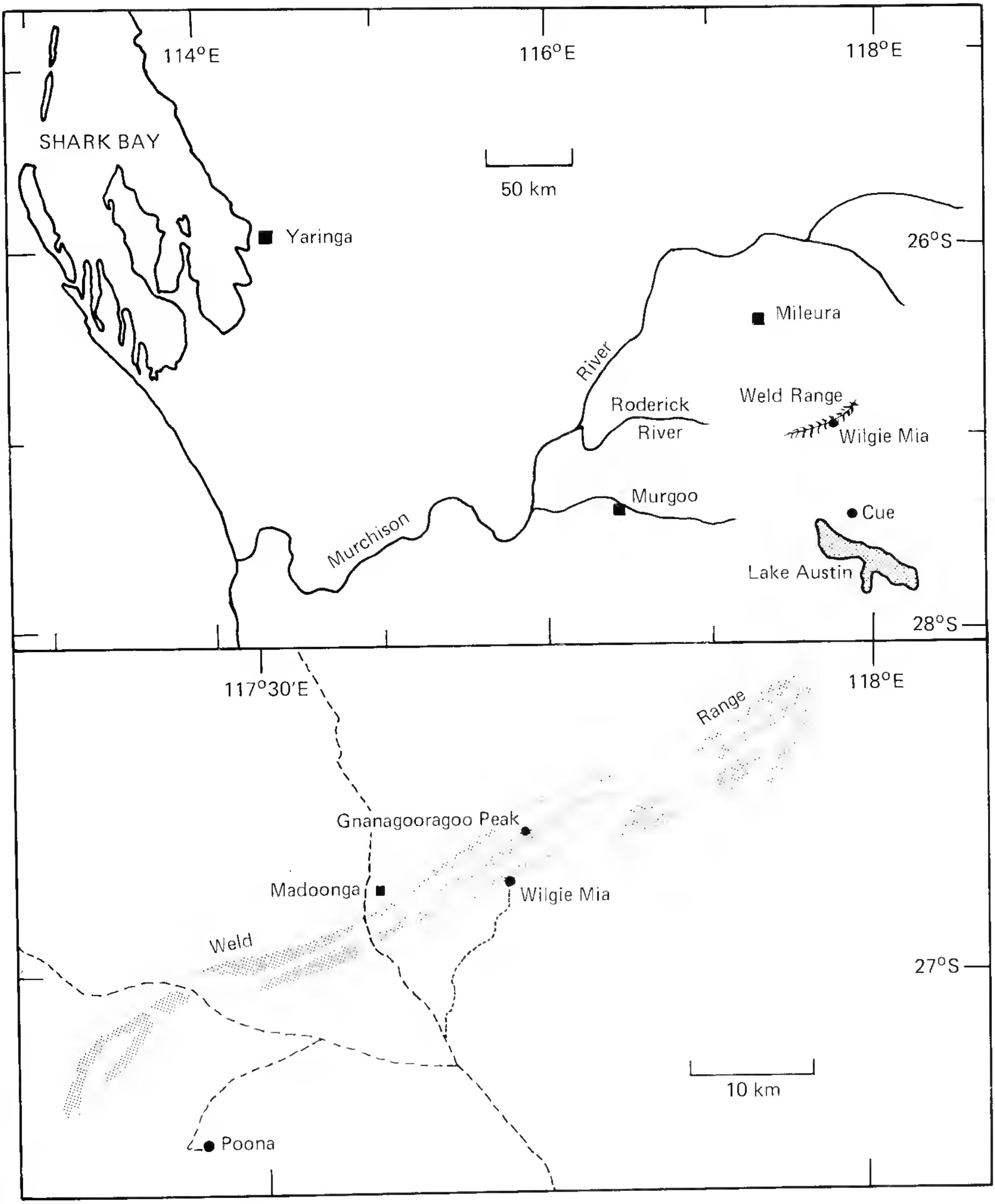

Figure 1 Locality maps.

The following account of the excavation was provided by Crawford (pers. comm.). Before the archaeological excavation was carried out, Europeans mined most of the loose ochre, only leaving pockets in recesses against the walls. It was one such pocket in the north-east wall of the main chamber that was excavated. Figure 2 represents a highly diagrammatic vertical section through the centre of the excavation. The 'talus' was loose ochre which had slumped down the face left by European mining operations. It was cleared from the stratified deposit a short section at a time. Adjacent *in situ* deposit was then excavated using trowels, placed into buckets and screened. The depth of accumulation against the wall was about 3.6 m; this was divided into layers designated 1 to 25 from the top down. A balk of unexcavated deposit was left between the wall and the layers 15 to 25. A pit was then excavated to a depth of about 1.8 m in the deposit between rocks contiguous with the base of the wall accumulation. Layers in the pit were designated 26 to 35. Bone material was only recovered from the wall deposit and the surface of the pit (layer 26); it is extremely well preserved.

Wood from layers 12 and 23 was submitted by Crawford for radiocarbon dating. The respective dates obtained were 560 ± 70 years B.P. (GaK-1769), and 1100 ± 90 years B.P. (Gak-1770). Additional information on the timing of the accumulation is provided by the account of Davidson (1952) of working by Aborigines until 1939. It therefore appears that the whole depth of loose ochre matrix against the wall has accumulated in approximately the last 1000 years. No date is available for material excavated from the pit, but Crawford considers that it probably continues the sequence.

Manner of Accumulation of Bones

Some of the bones recovered from the Wilgie Mia deposit, particularly those of larger species, are fully dissociated and free of remains of soft tissues. Many of the bones of small species, however, are less dissociated and still mixed with dried matted hair in elongated masses. These are almost certainly relatively unaltered owl pellets. It is probable that rapid burial of some material in the dry loose matrix allowed almost ideal preservation with no decay or attack by hair-eating insects. The form of pellets, and the location of the site in the arid zone, are consistent with Barn Owl (*Tyto alba*) as the predator.

Large carnivore scats from two layers were tentatively identified as from *Canis*, and are the basis for the inclusion of this species in the fauna. Humans were certainly working the mine at times. Either could have added bones, particularly of large animals. *Trichosurus vulpecula*, *Petrogale* species, and *Macropus robustus* use caves as daytime shelters, and could have died in Wilgie Mia. Crawford found the mummified carcase of a *T. vulpecula* (M5729) on the surface far into the workings.

Fossil Fauna

Table 1 shows the minimum number of individuals of each mammal taxon recorded from bone bearing layers in the Crawford excavation. Minimum numbers were taken as the highest counts of identified left or right skeletal elements. Post cranial, as well as cranial, material of larger species was identified and counted in the minimum number; it forms the basis of many of the tentative records.

There is indirect evidence of another native mammal having used Wilgie Mia as a day time shelter. A.M. Douglas has identified scat material from Wilgie Mia as that of *Macroderma gigas* (Bridge 1975). There is, however, no evidence on the age of the scats.

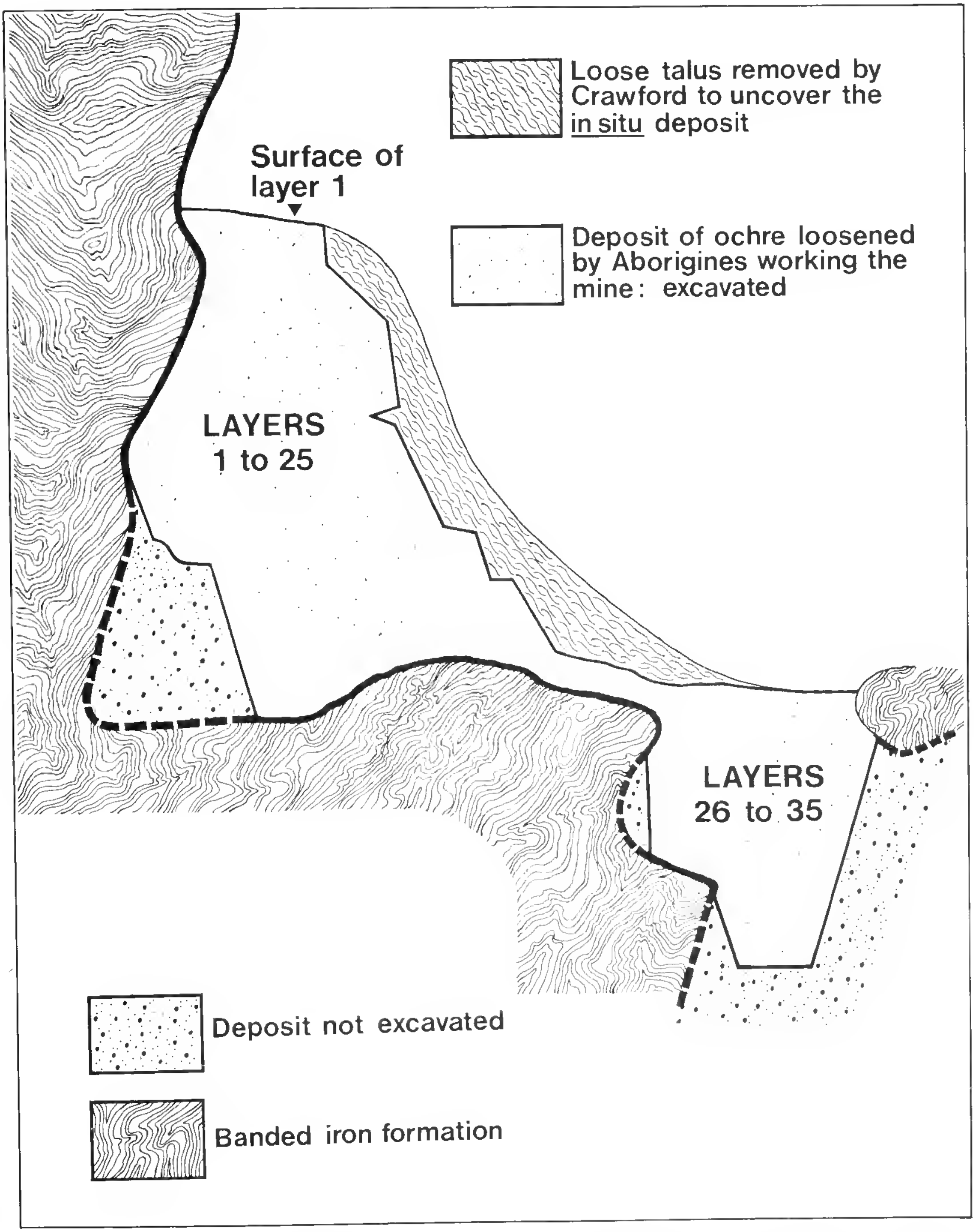

Figure 2 Diagrammatic vertical section through the centre of the Crawford excavation in Wilgie Mia.

Table 1 Minimum numbers of individuals of mammals from the Wilgie Mia excavation.

	Pseudomys nanus	*Pseudomys praeconis*	*Pseudomys hermannsburgensis*	*Leporillus apicalis*	*Leporillus conditor*	*Notomys* sp.	*Notomys longicaudatus*	*Rattus tunneyi*	Muridae indet.	*Canis* sp.	*Dasycercus cristicauda*	*Antechinomys laniger*	*Sminthopsis ooldea*	*Chaeropus ecaudatus*	*Trichosurus vulpecula*	Cf. *Lagorchestes hirsutus*	*Petrogale* sp. cf. *P. lateralis*	*Macropus robustus*	Large macropodine
Surface to base of Layer 3	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Surface talus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.
Layer 2A	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Layer 3	.	.	.	1	.	.	1	.	.	?	.	.	.	?	.	.	.	.	.
Layer 4	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Layer 5	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Talus below 5	.	1	.	?	.	1	.	.	.	.	.	1	.	1	.	.	.	.	.
Layer 6	.	.	.	.	.	.	.	.	1	.	?	.	.	.	.	.	.	.	.
Layer 8	.	.	.	.	.	1	1	?	.	.	.	.	.	.	.	.	.	.	.
Talus below 8	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Layer 9/11	.	3	2	1	.	6	3	8	.	?	3	2	.	1	1	.	.	.	?
Layer 11	.	1	.	.	.	1	.	5	1	.	1	.	.	.	.	.	.	.	.
Layer 12	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Layer 13	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	1	.	.
Layer 14	.	.	.	.	1	.	.	3	.	.	.	.	.	?	.	.	.	.	.
Layer 15	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.	.	.	.	.
Layers 1-16*	.	.	.	.	.	.	.	.	.	.	?	.	.	.	1	.	.	.	.
Layer 17	1	.	.	1	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.
Layer 18	.	.	.	1	.	.	.	2	.	.	.	.	1	.	1	.	.	.	?
Layer 19	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	?
Layer 20	.	.	.	.	.	.	.	1	.	.	1	.	.	?	.	.	.	.	?
Talus below 20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.
Layer 21	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.
Layer 22	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	?	.	.
Layer 23	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Layer 26	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.

* Section cleaning

? Indicates that remains representing one individual in the layer are tentatively referred to that taxon.

In addition to the mammal remains, bird bones were found in layers 9/11, 11, 12 and 22. In the absence of suitable reference material it was not possible to identify them further.

Discussion

The total number of individuals recorded from the deposit is only about 100. This sample size is far too small to enable trends, or even changes in presence/absence to be detected (see Baynes 1979). The high number of specimens and species in layers 9 to 11 probably reflects either a relatively long undisturbed occupation of the mine by owls, or one or more very good seasons, perhaps following rain from a tropical cyclone. It also suggests that several species in the fairly rich fauna occurred in the area at any one time. The owls probably hunted over the plains surrounding the range: remains of their small prey becoming mixed with those of the large prey of humans or dogs, and of species inhabiting the mine.

Most of the mammal remains from Wilgie Mia are less than 1000 years old. There is no information on changes in the arid zone faunas over that period, and the Wilgie Mia material does not provide any data. The specimens are therefore treated as records contributing to knowledge of the original ranges of the species, i.e. the ranges occupied prior to the arrival of European man.

Native mammals recorded from the Wilgie Mia district during European times are listed in Table 2. The almost complete dissimilarity of this fauna from the Wilgie Mia fossil fauna probably arises in part from different sampling biasses, as well as major local extinction. Remains of bats (five out of the 11 species in Table 2) are not usually common in owl accumulated assemblages, and no bat species is included in the Wilgie Mia fossil fauna, although all those listed in Table 2 are likely to have been present.

With the exception of *Macrotis lagotis,* which is based upon an early record, and is probably now extinct in the upper Murchison, all the species in Table 2 have generally survived well throughout their ranges during European times. Many of those in the Wilgie Mia fauna have not, and now appear to be either completely extinct, or extinct over much of their original ranges. Their presence makes the fossil fauna particularly interesting.

Table 2 Native mammal species collected alive within about 70 km of Wilgie Mia, based upon the modern mammal collection of the W.A. Museum.

Species	Locality closest to Wilgie Mia	Number	Date
Tachyglossus aculeatus	Cue area	M793	1926
Pseudomys hermannsburgensis	12 km SW Mileura homestead	e.g. M18623	1980
Notomys alexis	Poona	e.g. M6180	1964
Nyctophilus geoffroyi	16 km SSE Mileura homestead	e.g. M7547	1966
Chalinolobus gouldii	Madoonga station	M1657	1932
Eptesicus pumilus	Wilgie Mia (several series)	e.g. M5901	1963
Tadarida australis	Mileura homestead	e.g. M8325	1971
Taphozous hilli	Wilgie Mia (several series)	e.g. M3803	1960
Antechinomys laniger	Poona	M6082	1963
Sminthopsis crassicaudata	3 km west of Cue	M6617	1965
Macrotis lagotis	Cue area	e.g. M1129	1929
Macropus robustus	5 km south of Wilgie Mia	M5771	1963
Macropus rufus	4 km south of Wilgie Mia	M5499	1963

Most of the mammal species in the fossil fauna are, or were originally, widespread in the Australian arid zone. For some this distribution is already adequately documented. The Wilgie Mia records lie within the geographic ranges given by Watts and Aslin (1981) for *Pseudomys hermannsburgensis*, and *Notomys alexis* (the species probably represented by the indeterminable '*Notomys* sp.' from the deposit); by Ride (1970) for Dingo (assuming *Canis* is correctly identified in Wilgie Mia); by Archer (1977) for *Antechinomys laniger;* and by Frith and Calaby (1969) for *Macropus robustus*. Four of these five species are included in the modern fauna (Table 2), and Dingo also probably still occurs in the district. The records of all other species in the fossil fauna require discussion. Reference localities are shown in Figure 3 or Figure 1.

Pseudomys nanus was described by Gould (1858) from material collected by John Gilbert on the Victoria Plains. This is still the only locality in south-western Australia from which the species has been recorded as a living animal. The current species concept of *P. nanus* is that due to J.A. Mahoney (Ride 1970: 30), and includes the form occurring in northern Australia formerly known as *P. ferculinus*. The Wilgie Mia record thus lies between the original south-western Australian record and the northern Australian populations. It is significant because it is the first record in the subtropical arid zone of true *P. nanus*. (Before its recognition as a separate species, *Pseudomys desertor* was referred to as *P. nanus*, e.g. Watts and Aslin 1981.)

Pseudomys praeconis was for a long time known only from Shark Bay (e.g. Ride 1970), but its remains have now been recognised in surface cave deposits all along the west coast from Cape Leeuwin (Archer and Baynes 1973) to North West Cape (Kendrick and Porter 1974), although confirmation of the northern records by further material is desirable. The Wilgie Mia records are important because they show that *P. praeconis* was not restricted to near coastal habitats in its original distribution.

Neither species of *Leporillus* has ever been collected alive in Western Australia. Lundelius (1957) reported abundant remains of both species in surface deposits in caves of the Hampton Tableland. The Wilgie Mia records are part of the evidence that the original distributions of both species stretched westward across the southern arid zone to the west coast. *Leporillus apicalis* has been recorded from surface cave deposits in Cape Range, at Shark Bay and near Morawa (Kendrick and Porter 1974). There is also undated fossil *L. apicalis* material (e.g. 74.5.8) from a small cave on Murgoo Station in the middle Murchison. Remains of *Leporillus conditor* are abundant at the surface of deposits around Shark Bay: in sites on the Edel Land peninsula (Baynes 1979) and Dirk Hartog Island (see Burbidge and George 1978) on the western side, and on Yaringa Station (82.7.9) on the eastern side. There is also a specimen of *L. conditor* (67.4.42) from a small cave near Kalgoorlie.

Notomys longicaudatus probably had a very extensive original distribution in the arid zone. It was described by Gould (1844) from material collected for him by John Gilbert near 'Moore's River' (Gould 1863). Gilbert's Moore River locality was immediately north-west of the Victoria Plains, near where New Norcia stands today (Ride 1970: 20, 202). There are two specimens from the same area in the Leiden Museum (Mahoney 1969). In addition there is a modern specimen of *N. longicaudatus* in the Derby collections (Derby No. 412) in the City of Liverpool Museum (see below) from even further south at Toodyay. Kendrick and Porter (1974) reported one large maxilla from a cave deposit in Cape Range which J.A. Mahoney had indentified as possibly *N. longicaudatus* or *N. amplus*. I have re-examined the specimen (71.10.197). It is from an adult animal, but lacks molars and is broken. It retains enough of the zyogomatic plate to show that it is *Notomys*, and its shallow maxillary-premaxillary suture

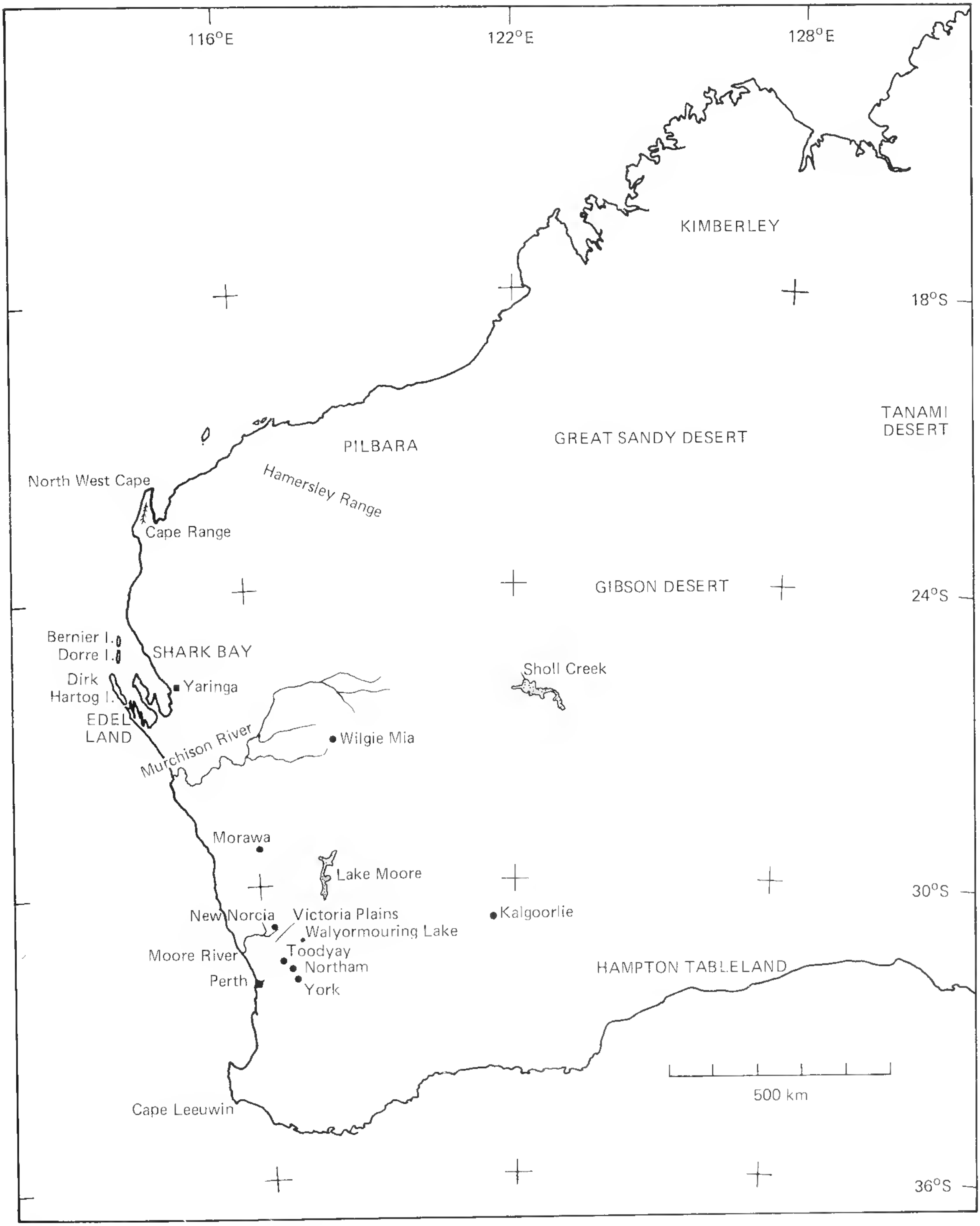

Figure 3 Map showing localities mentioned in the Discussion.

below the anterior edge of the zygomatic plate suggests that it is closer to *N. longicaudatus* than to *N. amplus*, in which this suture is very deep (cf. skull figure in Watts and Aslin 1981). In eastern and central Australia *N. longicaudatus* has been recorded as a living animal from north-western New South Wales and southern and central Northern Territory, and as a recent fossil from the Flinders Ranges (Watts and Aslin 1981), all within the arid zone.

The Wilgie Mia records of *Notomys longicaudatus* thus confirm its original presence in the arid zone of Western Australia. Its fairly high relative abundance in the deposit (six individuals in four layers) suggests that the species' habitat lay close to the Weld Range. Gilbert recorded that the species preferred 'a stiff and clayey soil' as a substrate (Gould 1863). The red earths of the plains around the Weld Range have a fairly high clay content and were probably suitable.

Rattus tunneyi is the most abundant species in the Wilgie Mia deposit. It originally ranged from the eastern to western coasts of mainland Australia, although some details of its distribution within that range are not clear, particularly in southern Australia (Taylor and Horner 1973). In south-western Australia it was collected alive near Perth and on the Victoria Plains (Mahoney 1969), and originally occurred right to the southern end of the west coast (Archer and Baynes 1973). It occurs as a fossil in surface deposits on the mainland at Shark Bay, on both the western side (Baynes 1979) and eastern side on Yaringa Station (82.7.14), and has recently been recorded (e.g. M8709) living on the west coast of the Edel Land peninsula. It was recorded in the fossil fauna from Cape Range (Kendrick and Porter 1974), and is extant on islands along the north-west coast and in Kimberley (Taylor and Horner 1973).

Rattus tunneyi was probably a resident member of the original mammal fauna of the Australian arid zone. It is only known as a living animal in this zone from Alice Springs and Tennant Creek (Parker 1973), where it was collected during or after the Horn Expedition; but this is the only area in the arid zone where the mammal fauna was reasonably well collected before being affected by European man. Brazenor (1936) considered that the central Australian specimens were smaller and had redder coloured pelage than the northern animals, suggesting a clinal situation. He named the central form *R. t. dispar*. However, Taylor and Horner (1973) included *R. t. dispar* in the northern *R. t. tunneyi* on the basis that the characteristics of *R. t. dispar* fall within the variation shown by populations of *R. t. tunneyi*. On the other hand, they allied the south-western populations with *R. t. culmorum* of eastern Australia, and postulated that the south-western population reached that area from the east via a southern migration route. Since the Wilgie Mia records probably represent the western part of an originally continuous arid zone population, there would have been gene flow between the west coast populations and those in northern Australia. The morphological similarity between south-eastern and south-western specimens probably reflects similar morphological response by the populations to high latitude or high rainfall, rather than close relationship.

Dasycercus cristicauda is widespread in the Australian arid zone (Ride 1970). The Western Australian Museum modern mammal collection includes specimens from the eastern Pilbara, e.g. M2745, Great Sandy Desert, e.g. M1497, and eastern Gibson Desert, e.g. M7742. The species is known from the surface of the cave deposits of the Hampton Tableland and west coast north of about latitude 31°S (Lundelius 1957), to Shark Bay (Baynes 1979, 82.7.1). The Wilgie Mia records thus lie in the gap between the modern desert records and the original occurrences along the west coast.

Sminthopsis oolda is restricted to the arid zone (Archer 1981). Archer's distribution map for the species (based upon pre-1977 data) shows the Wilgie Mia fossil specimen as the most westerly record in an arc stretching across the southern Northern Territory and northern South Australia. Wilgie Mia is still the species' known western range limit, but new records (e.g. M18243) have extended the known range northward to the limit of mulga formations, just south of the Hamersley Range. Dunlop and Sawle (1983) have suggested that this mulga line represents the northern limit of *S. ooldea* too.

The *Chaeropus ecaudatus* records from Wilgie Mia represent a substantial extension of range for the species. *C. ecaudatus* is only known to have been collected alive in Western Australia at Walyormouring Lake, some 500 km south of Wilgie Mia, whence it was obtained by John Gilbert (Calaby 1954).

Gilbert (letter No. 10 to Gould of 18 April 1843 [misdated 1842] *in* Wagstaffe and Rutherford 1955) originally wrote of only a single specimen obtained by the expedition to Walyormouring, and an intention to try to procure more; but later, in his notebook (*in* Whittell 1954) Gilbert mentions two specimens from Walyormouring. Gould (letter to Lord Derby of 3 July 1844 *in* Wagstaffe and Rutherford 1954) received two *Chaeropus* from Gilbert. One he sent to the British Museum and the other to Lord Derby for his collection at Knowsley Hall. The locality data with the Gilbert specimen in the British Museum were published as Boorda, Kirltana, W.A. (Thomas 1888). Gilbert's notebook shows that Boorda was the local Aboriginal name for *C. ecaudatus* (Calaby 1954), and Calaby considered that Kirltana was the name of the locality now lost.

The present label on the specimen is in Oldfield Thomas' handwriting (McNamara 1955) and records the locality as 'Boorda 40 mi. N.E. of Kirltana, W.A.' McNamara suggested that Kirltana might mean killed with a boomerang. Interestingly, Gilbert (*in* Wagstaffe and Rutherford 1955) originally stated that his specimen 'was brought from 40 miles N. East of Northam'; though it seems incredible that, however bad the handwriting, 'Northam' could have been rendered as 'Kirltana.'

In the hope of casting further light on the matter I tried to trace the Derby specimen. The Derby collections were bequeathed to the City of Liverpool, and stored in the City of Liverpool Museum. Mr J.I. Harris, the Assistant Keeper of Vertebrate Zoology, kindly searched Derby catalogues and the collection for me in 1973. The first volume of the *Catalogue of the mammals in the Knowsley Museum*, covering Nos 1-350, contains the following entry:

260 | *Chaeropus castanotis*, Gray
Purchased of Mr Gould July 1844
Habitat Swan River
a | Do Do
Presented by Capt. Sturt Nov. 1847
From Australia

Chaeropus castanotis Gray, 1842 is a junior synonym of *C. ecaudatus* (Ogilby, 1838). There appears to be no reason to doubt that number 260 was a second specimen obtained by Gilbert in Western Australia. However, the catalogue entry adds no information on the source locality of the specimen ('Swan River' is almost certainly an abbreviation for Swan

River Colony rather than a precise locality, as Gilbert (*in* Whittell, 1954) noted that Walyormouring marked the western range limit of the species). It is probable that No. 260, like other Gilbert specimens still in the Derby collection, retained Gilbert's original label, but unfortunately neither of the Derby *Chaeropus* can be found. Both appear to have been destroyed when the museum was bombed in 1940.

The Derby catalogue entry for the *Chaeropus ecaudatus* presented by Sturt is interesting, because it suggests that Sturt did obtain the species when exploring central Australia between 1844 and 1846. Ride (1970: 102), presumably unaware of this record, stated that Sturt's account of the natural history of the animal was probably based on another species.

Glauert (1950) quoted a letter from Sanford in the preface to the journal of an expedition led by Austin in 1854, where it is stated that *Chaeropus* was met with in large numbers on the journey. The expedition travelled north past Lake Moore towards Shark Bay and crossed the Roderick River, which is a tributary of the Murchison rising near the Weld Range. No specimens appear to have been preserved from this expedition, so it is difficult to assess the validity of this identification.

Chaeropus has also been recorded from the Hampton Tableland, where its remains are widespread in the many caves of the area (Merrilees 1968). To the east the species has been recorded from the arid zone of South Australia and the Northern Territory (Ride 1970); plus south-western Victoria, near the junction of the Murray and Murrumbidgee Rivers (Wakefield 1966).

Trichosurus vulpecula probably ranged over most of subtropical western Australia before the arrival of European man, wherever there were trees or deep rock clefts to provide day time shelter. The Western Australian Museum modern mammal collection includes only one record from the arid zone: M424 from Sholl Creek; but Spencer (1896: 16) recorded that, at the time of the Horn Expedition, the species was common in the eucalypts marking many creek beds in central Australia. The Wilgie Mia records lie some distance from any others, but confirm the presence of the species in the western arid zone.

Lagorchestes hirsutus was probably originally distributed over much of semi-arid and arid Western Australia, from York, where it was first obtained by John Gilbert (Thomas 1888), to the Great Sandy Desert (e.g. M1471). Extant populations are now only known on Bernier and Dorre Islands in Shark Bay, and in the Tanami Desert in the western Northern Territory (Bolton and Latz 1978). Wilgie Mia lies within this range.

Petrogale lateralis is another widespread species whose original range included much of semi-arid and arid Western Australia. The Weld Range is probably a most suitable habitat for such rock-wallabies.

Conclusion

The fossil mammal fauna from Wilgie Mia suggests that many mammal species were far more wide ranging in the arid zone, before they were affected by European man, than is apparent from records based upon live-caught specimens. Thus the fauna includes not only such species as *Pseudomys hermannsburgensis, Antechinomys laniger* and *Macropus robustus,* which are known on the basis of abundant modern records to occur over large proportions of the arid zone, and to have survived well in the face of European colonisation, but also such mammals as *Pseudomys praeconis, Leporillus apicalis, L. conditor, Notomys longicaudatus* and *Chaeropus ecaudatus* which are known from very few localities and are not known to survive anywhere in the arid zone on the mainland.

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I thank Dr I.M. Crawford for making the Wilgie Mia material available for study. Dr M. Archer, Mr J.A. Mahoney and Dr D. Merrilees assisted with identifications of, respectively, small dasyurids, large *Notomys* and macropodids. Dr Merrilees, Dr W.D.L. Ride and Dr K.J. McNamara provided constructive criticisms of drafts, and Mrs R. Henderson prepared Figure 2. I would also like to thank Mr J.I. Harris for putting considerable time and effort into searching the Derby catalogues and the collections of the City of Liverpool Museum for the *Chaeropus* records and specimens. Finally, I am most grateful to the Western Australian Museum for the provision of facilities, including the assistance of excellent typists Mrs Marian Konstantinu and Mrs Jan Paniperis.

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SHORT COMMUNICATIONS

Rec. West. Aust. Mus. 1984, 11 (3): 313-314

A New *Ramphotyphlops* (Serpentes: Typhlopidae) from Central Australia

G.M. Storr*

Abstract

A new blind-snake, *Ramphotyphlops centralis*, is described from the Alice Springs district.

Introduction

Recently Mr M.W. Gillam sent me for identification a parcel of reptiles from the collection of the Conservation Commission of the Northern Territory, Alice Springs (NTM A/S). Among them were six specimens of an undescribed blind-snake.

Ramphotyphlops centralis sp. nov.

Holotype

R317 in NTM A/S, a male collected in October 1976 at Alice Springs, Northern Territory, in 23°42′S, 133°52′E.

Paratypes (all in NTM A/S)

Northern Territory

Alice Springs (5890, 5895, 5906, R138); Pine Gap (5888).

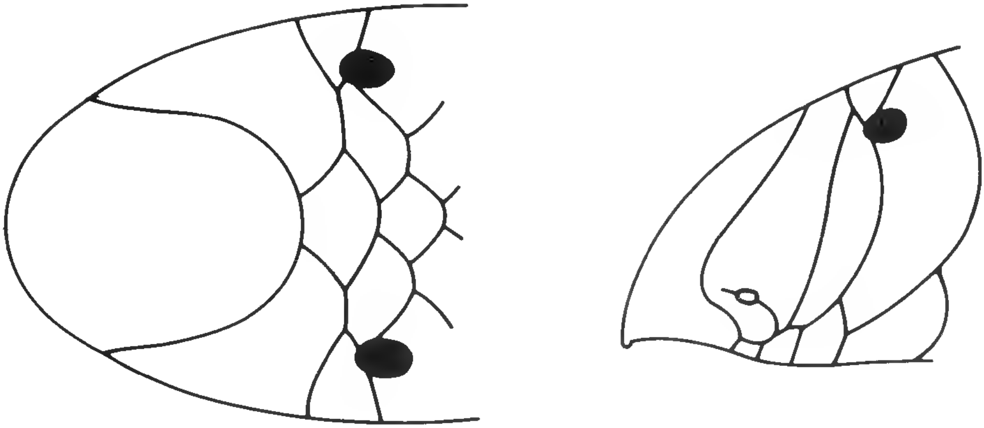

Figure 1 Head of *Ramphotyphlops centralis*.

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Diagnosis

A moderately slender *Ramphotyphlops* with 20 midbody scale rows and nasal cleft proceeding from second labial; snout relatively short and tipped with cutting edge.

Description

Total length (mm): 165-306 (N 6, mean 246). Length of tail (% total length): 1.5-3.1 (N 6, mean 2.5).

Rostral from above elliptic, longer than wide, and extending back nearly to level of eyes. Nasals narrowly separated behind rostral. Snout tipped with strong, dark transverse cutting edge which extends back as a ridge on to nasal scale just above nostril. Nostrils inferior, much nearer to rostral than preocular. Nasal cleft proceeding from second labial (N 6) to nostril or a little beyond, but never crossing nasal ridge or reaching rostral.

Midbody scale rows 20 (N 6). Ventrals 405-482 (N 6, mean 434.8). Subcaudals 12-20 (N 6, mean 17.5).

Upper surface purplish-brown, gradually merging with pale lower surface.

Distribution

Alice Springs and vicinity, Northern Territory.

Remarks

This snake is a member of the group of species that includes *R. unguirostris*, *R. australis*, *R. hamatus* and *R. endoterus* (Storr 1981). Of these species, *R. centralis* is most like *R. hamatus*, which it resembles closely in the shape and scutation of the head. However, *R. hamatus* has more midbody scale rows (22), fewer ventrals (less than 400) and a sharp jagged boundary between the dark upper and pale lower surfaces.

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Subspecific Status of the Painted Button-quail of the Houtman Abrolhos, Western Australia

G.M. Storr* and R.E. Johnstone*

Peters (1934: 148) was uncertain of the validity of *Turnix varia scintillans* (Gould) of the Houtman Abrolhos. Condon (1975: 98) accepted it; his diagnosis was evidently adapted from the excellent description in Gould (1865: 181).

Although the disparity is not as great as Gould believed, Abrolhos birds are certainly smaller than those from throughout the mainland of south-western Australia (specimens examined from Yuna, Trayning, Canning Vale, Canning River, Dongolocking, Chorkerup and Wilsons Inlet). For example, length of wing is 87-89 mm in two males, 91 in one female and 85-92 mm in seven unsexed specimens from the Abrolhos, compared with 96-101 in five males and 102-112 in four females from the mainland. The weight of nine Abrolhos birds ranged from 52 to 82 g, v. 85-112 in three mainland specimens.

Differences in dorsal coloration mostly concern the chestnut feathers of the back and rump. The transverse black bars on these feathers are narrower in Abrolhos birds than on the mainland, and they do not tend posteriorly to coalesce into large black blotches. A higher proportion of the chestnut feathers in Abrolhos birds are laterally edged with white; moreover these white margins are broader and not tinged with grey. The white dorsal streaks are consequently more numerous and more conspicuous than in mainland birds. Similarly the white spots on the wing coverts are more conspicuous in Abrolhos birds; they are smaller and tinged with grey on the mainland.

Abrolhos birds are paler ventrally, e.g. the abdomen is buffy-white, v. reddish-buff on the mainland. The pale quadrangular marks on the breast tend to have the longer axis transverse in the Abrolhos, longitudinal on the mainland (Gould described this difference as 'crescentic' v. 'elongated').

In conclusion, *T. v. scintillans* is worthy of recognition. It is confined to North Island and the Wallabi Group.

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Note on *Tympanocryptis lineata macra* (Lacertilia: Agamidae)

G.M. Storr*

In 1982 I separated *T. l. macra* of eastern and central Kimberley from *T. l. centralis* of southern Kimberley and Central Australia. *T. l. macra* was characterised mainly by its longer legs and tail. Other differences are apparent in material recently collected in the Kimberley by G. Harold and D. Mead-Hunter, viz. five specimens of *T. l. centralis* from the upper Margaret River drainage between Lamboo and Louisa Downs, and three specimens of *T. l. macra* from north of Kununurra.

In *T. l. centralis* the dorsal ground colour is reddish and the colour pattern is strongly developed, including a white vertebral stripe which is twice as wide as a dorsolateral stripe. In *T. l. macra* the dorsum is greyish, the pattern weakly developed and the vertebral stripe no wider than a dorsolateral stripe. These differences in ground colour reflect differences in habitat: *T. l. centralis* prefers red soils in the vicinity of rocks and stony hills; *T. l. macra* prefers black-soil plains.

Another difference is that *T. l. macra* is more strongly keeled above and below, especially in the north-easternmost part of its range. Here the head scales, especially those on the occiput, are rugose as well as sharply keeled.

I am grateful to Mr and Mrs W.H. Butler, whose grant to the Museum financed Harold and Mead-Hunter's trip to the Kimberley in February 1984.

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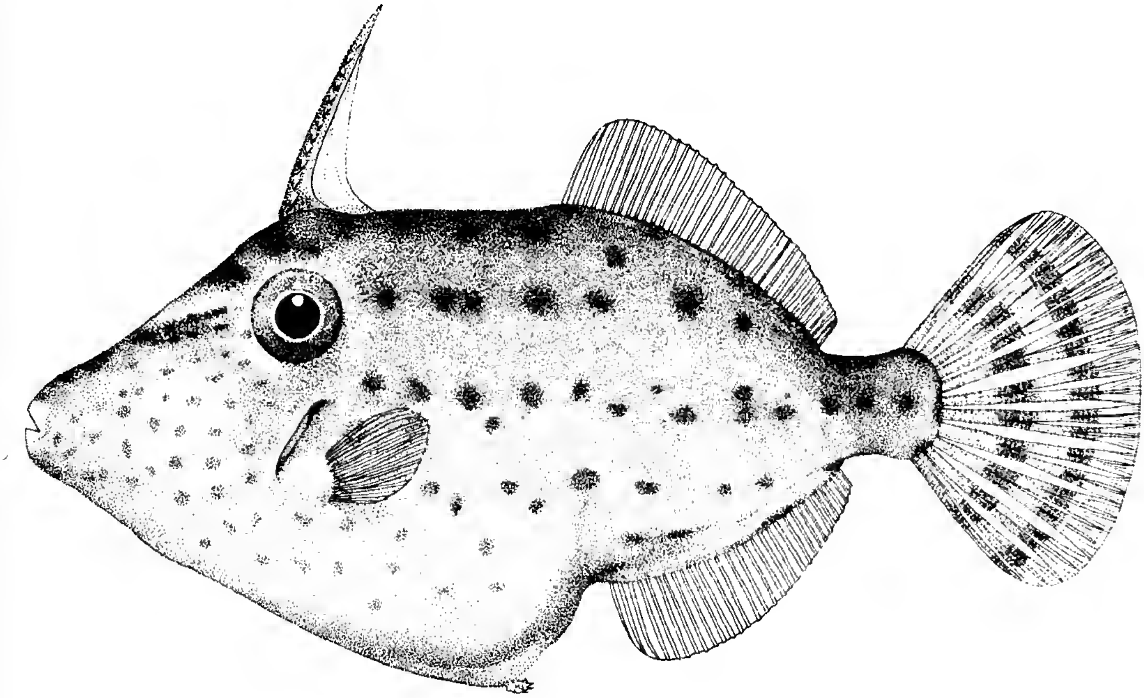

Rec. West. Aust. Mus. 1984, 11 (4): 319-356

A Revision of the Spatangoid Echinoid *Pericosmus* from the Tertiary of Australia

K.J. McNamara* and G.M. Philip†

Abstract

McCoy's (1882) *Pericosmus gigas, P. nelsoni* and *P. compressus* are reinvestigated and described. *P. gigas* is referred to *Victoriaster, P. nelsoni* is made type species of *Waurnia* gen. nov. and *P. compressus* is redescribed as *P. maccoyi* Gregory, 1890. McCoy's species is a junior homonym of Duncan's (1877) *Megalaster compressus* which is redescribed as *P. compressus*. New species of *Pericosmus* described are the Longfordian *P. celsus*, the Longfordian-Batesfordian *P. torus* and the Bairnsdalian *P. quasimodo*. Two further species of *Pericosmus* are described as new, but left in open nomenclature on account of paucity of material. Evolutionary trends within Australian species of *Pericosmus* are examined in terms of the functional significance of the morphological adaptations.

Introduction

In 1882 Frederick McCoy described three large spatangoid echinoids from the Tertiary rocks of Victoria, *Pericosmus gigas* (said by McCoy to be of Early Miocene age from the Murray River). *Pericosmus nelsoni* (of Late Oligocene Janjukian age from Waurn Ponds) and *Pericosmus compressus* (of Janjukian age from Bird Rock Point, near Torquay).

Pritchard (1908) rightly questioned the correctness of McCoy's placement of *Pericosmus gigas* in *Pericosmus* for, as McCoy himself noted, the marginal fasciole, characteristic of *Pericosmus*, was lacking in the anterior part of the test. Pritchard, in addition to describing a further species, placed them both in *Linthia*. Lambert (1920), however, proposed the genus *Victoriaster* to accommodate *P. gigas*, considering its large size, long petals and anterior disappearance of the 'marginal' fasciole diagnostic. Mortensen (1951) concluded that no satisfactory generic separation of *Victoriaster* from *Pericosmus* could be entertained as absence of the marginal fasciole was not, he believed, definitely established in *P. gigas*. Fischer (1966) adopted a more conciliatory attitude and made *Victoriaster* a subgenus of *Pericosmus*.

Pericosmus nelsoni has likewise suffered from assignment to various genera. Pritchard (1908) considered the species to possess a lateroanal fasciole and not a marginal fasciole, and so placed it in *Linthia*. Lambert (1905) placed it in *Peribrissus*. Lambert and Thiéry (1924),

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however, believed the weakly developed ambulacrum III and anteriorly positioned apical system warranted placement in *Prenaster*. H.L. Clark (1946) also preferred to regard it as a species of *Linthia*.

Since McCoy's original paper, many more specimens of these species have been collected, particularly through the agencies of F. Cudmore and F. and R. Foster. On the basis of these collections housed in the palaeontological collections of the Museum of Victoria (NMV), Department of Geology, University of Melbourne (MUGD), the South Australian Museum (SAM) and the Western Australian Museum (WAM), we redescribe McCoy's species and offer our opinion as to which genera they should be assigned. In addition, we describe three new species of *Pericosmus* and reinterpret the type species of *Victoriaster*, *V. gigas*. The abbreviation TL is used throughout for test length.

Henderson (1975) has pointed out the confused status of Australian species of *Pericosmus*. This has arisen, we believe, because of the large degree of ontogenetic variation which occurs through growth. We document these changes and suggest possible interrelationships between the species and the functional significance for morphological changes that occur between them.

Systematics

Order Spatangoida Claus, 1876

Family Pericosmidae Lambert, 1905

Remarks

Chesher (1968), followed by Henderson (1975) and Kier (1984), placed *Pericosmus* in the Paleopneustidae as he believed *Pericosmus* belongs in the same family as *Paleopneustes*, and that Paleopneustidae Agassiz has priority over Pericosmidae Lambert. They both consider that these two genera, along with *Plesiozonus*, *Faorina* and *Antillaster*, share a number of common morphological characteristics, principal among which are a particular place configuration in adoral interambulacrum 1, and paired pores in each phyllodal peripodium. Leaving aside the efficacy of the use of these particular morphological features as familial characteristics, we cannot accept that *Pericosmus* belongs within the Paleopneustidae, principally because many of the extinct species, including the type species *P. latus* (Agassiz) (Henderson 1975, Fig. 11d), do not have the peculiar place configuration attributable to the family. The second interambulacral plate of interambulacrum 1b abutts both ambulacra I and II in *Paleopneustes*, *Faorina*, *Plesiozonus* and some modern species attributed to *Pericosmus*, although McNamara (1984) has noted how even within the living species *P. porphyrocardius* McNamara, 1984, the plate configuration is variable. In all Australian fossil species of *Pericosmus* and in *P. latus* the second place is 'normal' in abutting only ambulacrum II (e.g. Figure 12).

We prefer, at present, to retain the family Pericosmidae Lambert, the diagnostic feature being the presence of both a peripetalous and a marginal fasciole. However, we note (below) that the peripetalous and marginal fascioles are not always entirely separate, as in *P. celsus* sp. nov., *P. quasimodo* sp. nov. and *P.* sp. A. In these species the anterior branches of the peripetalous fasciole run exsagittally in interambulacra 2 and 3 to join the marginal fasciole.

Genus *Pericosmus* Agassiz, 1847

Type Species

Micraster latus Agassiz, 1840; by subsequent designation of de Loriol (1875: 115).

Pericosmus compressus (Duncan, 1877)

Figures 1-4

Megalaster compressa Duncan, 1877: 62, Fig. 1; – Duncan 1887: 422-433; – Tate 1891: 271 (pars.).
Pericosmus compressus - Gregory 1890: 485-486, *non* Pl. 14, fig. 1 (*Schizobrissus dicepiens* Tate); – Lambert and Thiéry 1924: 513.
Linthia compressus – H.L. Clark 1946: 366
Pericosmus crawfordi (pars.) – Henderson 1975: 54-57.
non Pericosmus compressus McCoy, 1882: 21-22, Pl. 67, figs 2-2a, Pl. 68.

Holotype

British Museum (Natural History) specimen E296 from the 'Banks of the Murray;' by monotypy; it probably derived from the early Middle Miocene Morgan Limestone of Batesfordian to Balcombian age.

Other Material

This study is also based upon 15 further specimens: NMV P17912, 17913, 18102, 18103, 18364, 55513-55522 from the Morgan Limestone on the banks of the Murray River between Overland Corner and Morgan, South Australia.

Diagnosis

Test low to moderately inflated; interambulacrum 5 most swollen adapically. Apical system situated a little anterior of centre. Ambulacrum III sunken throughout, deep adapically. Paired petals broad and deep with up to 34 pore pairs in anterior pair. Peristome sunken, broad. Labrum projects anteriorly, almost extending across peristome.

Description

Test reaches a maximum known length of 133 mm. Smallest known specimen has a test length of 41 mm. In plan, test almost circular, but slightly longer than broad; with an anterior notch which is shallow and broad in small specimens (Figure 3B), but becoming progressively deeper and relatively narrower with increasing test size (Figure 2). The holotype, however, retains the juvenile broad notch, even though it is 120 mm long (Figure 1). Test of small specimens tumid, with a height up to 64% test length (TL). With growth, test becomes relatively lower as length and width increase at a greater rate than height; in large specimens height ranges from 41 to 50% TL. Anterior and lateral interambulacra gently convex, although becoming flattened to slightly concave adapically. Posterior interambulacrum has a pronounced keel adapically (Figure 4). Test highest at this point in both small and large specimens. Apical system sunken; with three genital pores; ethmolytic and situated between 35 and 44% (TL) from anterior ambitus. This range of values largely reflects a slight relative anterior movement of apical system with growth.

Ambulacrum III depressed, but shallow adapically, becoming deeper abapically, particularly in large specimens; bearing up to 23 sets of very small pore pairs. Anterior paired petals diverge at about 125°; longer than posterior petals in small specimens less than 45 mm TL

Figure 1 *Pericosmus compressus* (Duncan, 1877): BM E296, holotype, from the 'Banks of the Murray;' probably Morgan Limestone; aboral view, × 1.

(Figure 3B); at 70 mm TL petals of equal length; at 85 mm TL and greater, anterior petals shorter than posterior (Figure 2); 24-30% TL; bearing 20-22 pore pairs in small specimens between 41-45 mm in length, increasing to a maximum of 34 at a test length of about 100 mm. Posterior petals bear up to 38 pore pairs; petals diverge at about 60°; 20% TL in small specimens, increasing to 30% TL in large specimens. Anterior and posterior petals broad in all specimens, but shallow in small specimens and progressively deepening with growth.

Peripetalous fasciole indented to half petal length between petals; anteriorly it runs adambitally through three interambulacral plates of interambulacra 2a and 3b before crossing to 2b and 3a respectively; thence crossing two plates before running transversely across ambulacrum III. Anteriorly it may be ill-defined or missing.

Figure 2 *Pericosmus compressus* (Duncan, 1877): NMV P18364, from the Murray River cliffs, between Overland Corner and Morgan; Morgan Limestone; aboral view; × 1.

Peristome broad, particularly in large specimens, where it reaches up to 18% TL (Figure 3A); situated close to anterior notch; with growth becoming more sunken. Labrum arches strongly forward and almost crosses peristome (Figure 3A). Pores in phyllode paired; 9 pairs in ambulacra II and IV; 6 in ambulacrum III and in ambulacra I and V. Plastron gently convex; width 32-46% TL. Periplastronal width 12-15% TL. Periproct transversely oval, long axis 13% TL; slightly sunken. Subanal area depressed.

Remarks

Duncan (1877) based *Megalaster compressa* on a single specimen from the banks of the Murray River (Figure 1). McCoy (1882) gave *Pericosmus compressus* the same specific name as *Megalaster compressus* Duncan, 1877 as he believed that Duncan's species, said to lack fascioles, was based on a poorly preserved specimen of *Pericosmus* in which the fascioles had

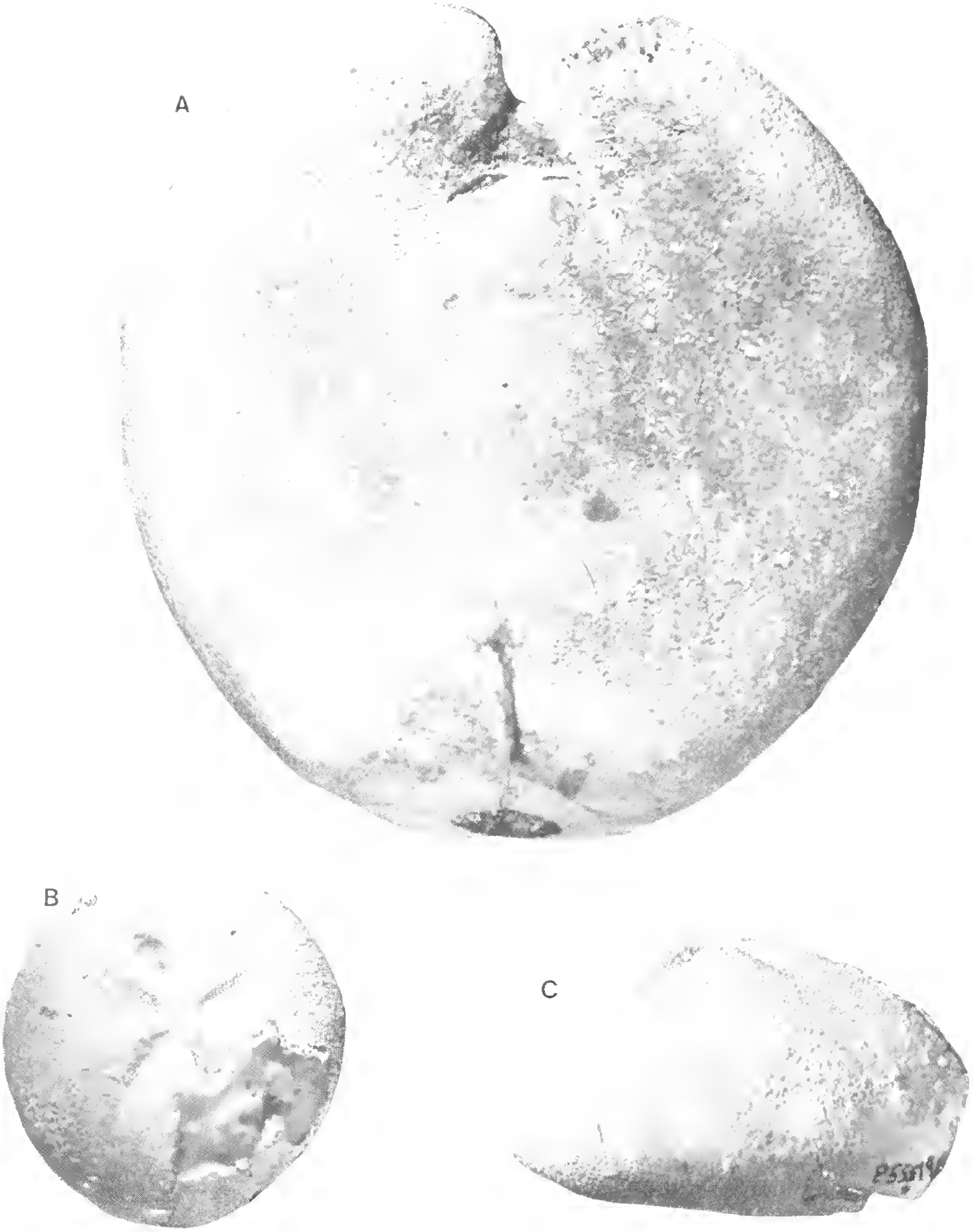

Figure 3 *Pericosmus compressus* (Duncan, 1877); (A) adoral view of NMV P55515; (B) aboral view and (C) lateral view of NMV P55519; all specimens from the Morgan Limestone from the Murray River cliffs, between Overland Corner and Morgan; all × 1, except (C), × 1.5.

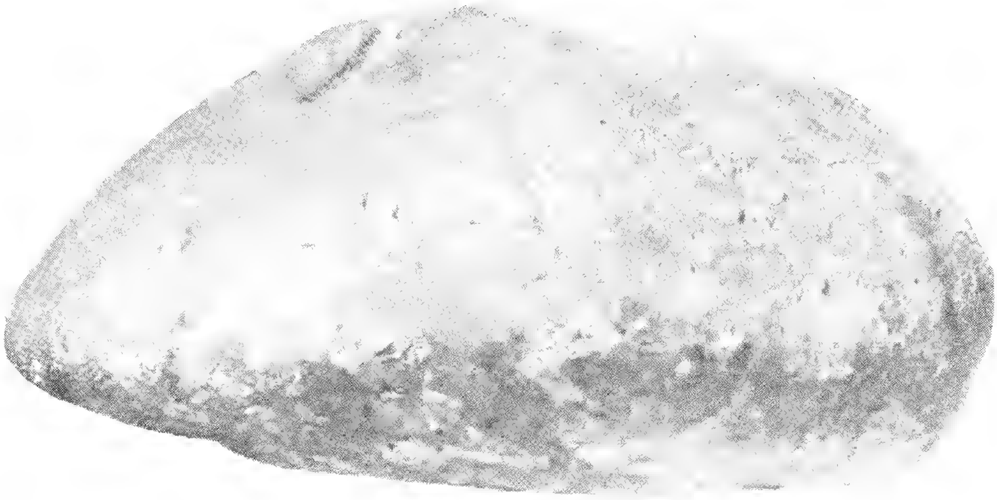

Figure 4 *Pericosmus compressus* (Duncan, 1877); NMV P18364, from the Murray River cliffs, between Overland Corner and Morgan; Morgan Limestone; lateral view; ×1.

been obliterated by weathering, and that Duncan's genus would prove synonymous with *Pericosmus*. Duncan (1887) maintained that his specimen in the British Museum (Natural History) (BM E296) lacked all trace of fascioles, a claim reaffirmed by Gregory (1890). However, inspection of the specimen by one of us (G.M.P.) has revealed both peripetalous and marginal fascioles to be clearly visible on the right side of the test. *Megalaster* is thus a junior synonym of *Pericosmus* and, to this extent, McCoy's judgement is vindicated.

McCoy (1882) believed his *Pericosmus compressus* from Bird Rock Point, near the mouth of Spring Creek, 25 km south of Geelong, Victoria, would prove synonymous with Duncan's species, which he considered should be placed in *Pericosmus*. Gregory (1890), however, considered McCoy's specimen to be specifically distinct from Duncan's, naming it *P. maccoyi*. Differences noted by Gregory do not correspond well with the characteristics of McCoy's (1882, Pl. 67, fig. 2, Pl. 68) figure. The apical system is too anterior, the frontal notch and petals are too broad. Examination of McCoy's specimen (NMV P4834) reveals that most of the aboral surface of the test is missing, but sufficient is preserved to show the characteristic short, narrow petals of the species. Further material from Janjukian strata in the vicinity of Bird Rock Point (see below) confirms *P. maccoyi* as being specifically distinct from *P. compressus* (Duncan). Unfortunately, the holotype of *P. compressus* has a much broader anterior notch than is normal for a specimen 118 mm in length. And to compound the problem, the anterior notch of the holotype of *P. maccoyi* is narrower than in topotype specimens.

Much of the confusion regarding the identification of species of *Pericosmus* arises from the degree of morphological distinction between small and large specimens of the same species (contrast Figures 3B, C and Figures 2, 4). Changes with growth include a relative decrease in test height; swelling of adapical interambulacra; increasing length of posterior petals relative to anterior petals; increase in petal depth; increase in depth of anterior notch;

increasingly sunken peristome. Mortensen (1950, 1951), in describing some living adult specimens, noted their characteristic shallow anterior notch; shallow petals; and anterior paired petals which are longer relative to the posterior petals. Larger living species on the other hand, have characteristics in common with large specimens of *P. compressus*. We suspect that the large number of specific names applied to living members of the genus is due to the fact that the extent of morphological changes during ontogeny has not been recognised.

Hutton (1887) and Tate (1894) considered that *Meoma crawfordi* Hutton from Oligo-Miocene strata in New Zealand was a synonym of *P. compressus*. Tate (op. cit.) further added that *Meoma brevipetala* Hutton was based on a crushed specimen of *P. compressus*. Henderson (1975) reiterated Hutton's (1894) view, placing *P. compressus* in synonymy with *P. crawfordi*. *P. compressus* is, however, clearly distinguishable from *P. crawfordi* as it possesses a deeper anterior notch; frequently a more highly vaulted test; a more anteriorly positioned, broader peristome; a labrum that projects further anteriorly; and adapically swollen interambulacrum 5. *P. compressus* differs from the type species, *P. latus* Agassiz, in possessing a deeper anterior notch, a more anteriorly eccentric apical system and in attaining a much larger adult size.

Pericosmus maccoyi Gregory, 1890

Figures 5, 6

Pericosmus compressus McCoy, 1882: 21-22, Pl. 67, figs 2-2a, Pl. 68.
Pericosmus maccoyi Gregory, 1890: 485-486.

Holotype

NMV P4834 from Bird Rock Point, near the mouth of Spring Creek, 25 km south of Geelong, Victoria; Late Oligocene, Janjukian; by monotypy.

Other Material

NMV P18759, 18760, 20141, 20146, 20179 from same locality and horizon as holotype; NMV P20206 from Janjukian or Longfordian (Late Oligocene to Early Miocene) Gambier Limestone at Port MacDonnell, South Australia; NMV P20201 from the Gambier Limestone at Mt Gambier, South Australia.

Diagnosis

A species of *Pericosmus* with low, relatively small test; little adapical swelling of the interambulacra. Ambulacrum III shallow; anterior notch broad. Paired petals short.

Description

Test reaches a maximum known length of 103 mm. In plan, test nearly circular, sometimes wider than narrow. Anterior notch broad, moderately depressed, although being quite narrow in the holotype (NMV P4834). Test low, gently convex, height not exceeding 48% TL. Posterior ambulacrum without pronounced keel (Figure 6B). Test highest apically, with no adapical ambulacral swelling. Apical system situated slightly anterior of centre (37-44% TL from anterior ambitus). Ambulacrum III shallow, not sunken at all adapically. Anterior paired petals diverge at about 125°; short; shallow; of equal length to posterior petals, occupying 21-27% TL; up to 27 pore pairs in anterior petal. Peristome narrow (12% TL)

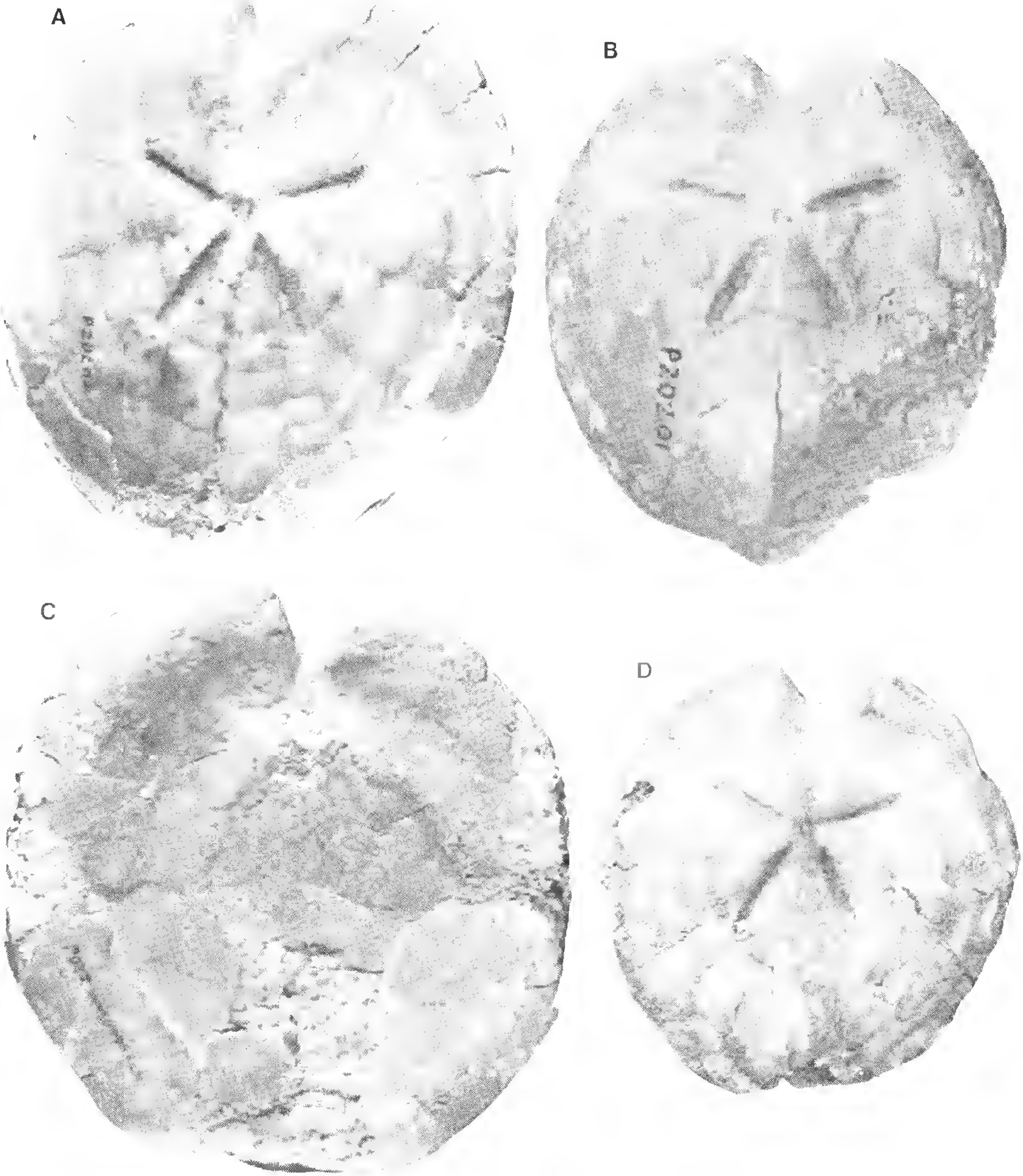

Figure 5 *Pericosmus maccoyi* Gregory, 1890; (A) aboral view and (C) adoral view of NMV P20206, form the Gambier Limestone at Port MacDonnell; (B) aboral view of ANMV P20201, from the Gambier Limestone at Mt Gambier; (D) aboral view of NMV P20141, from Janjukian strata at Bird Rock Point; all ×1.

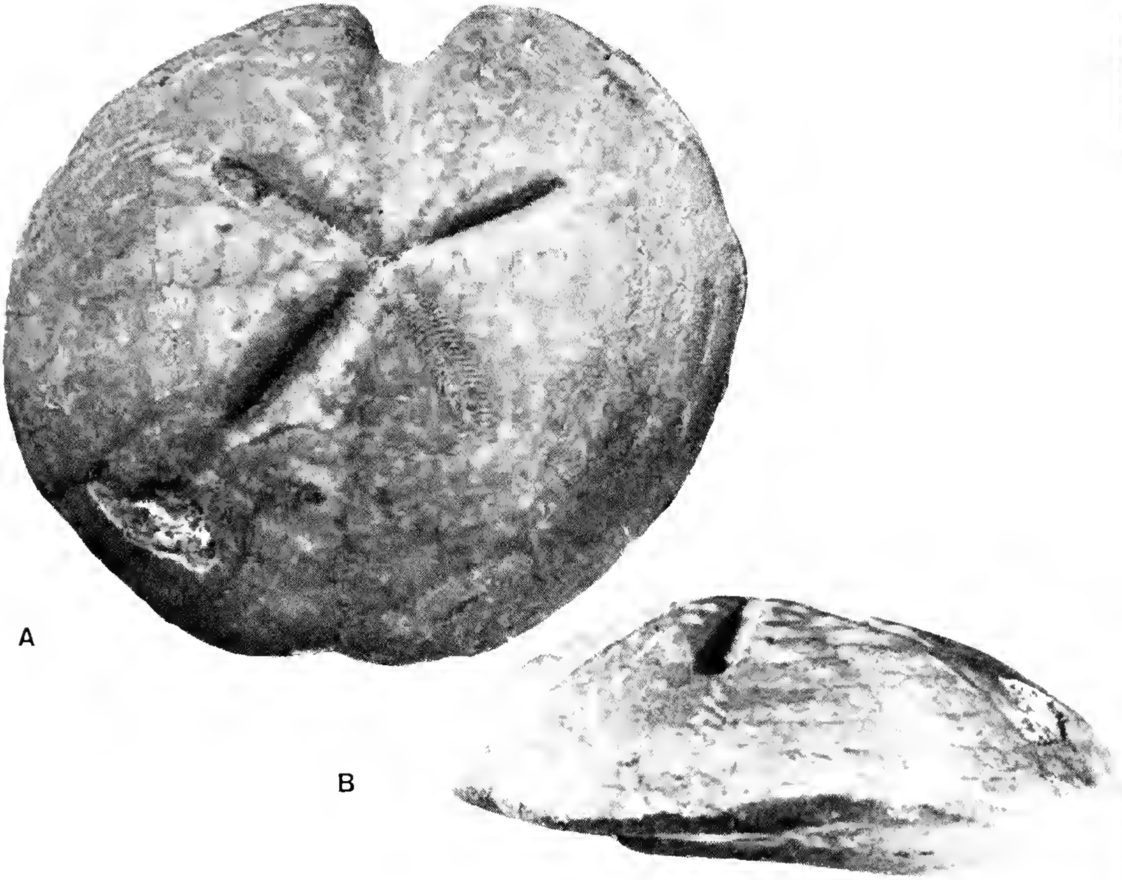

Figure 6 *Pericosmus maccoyi* Gregory, 1890; (A) aboral view and (B) lateral veiw of NMV P20146, from Janjukian strata at Bird Rock Point; both × 1.

with labrum which does not project appreciably forward. Plastron narrow, width ranging between 33-41% TL.

Remarks

P. maccoyi is the oldest known species of *Pericosmus* in the southern Australian Tertiary, first appearing in the Janjukian Stage and ranging into the Longfordian. It is most similar to *P. compressus* in having a relatively low test and similarly positioned apical system. However, it can be distinguished by its shorter, shallower paired petals, shallower ambulacrum III, broader anterior notch; absence of appreciable swelling in interambulacra adapically; narrower peristome and less anteriorly projecting labrum.

P. maccoyi is also similar to *P. crawfordi* from the Oligo-Miocene of New Zealand, but can be distinguished by its more centrally positioned apical system; its broader anterior notch; its shorter paired petals; and its shallower ambulacrum III aborally. *P. annosus* Henderson, 1975 from the Late Eocene of New Zealand, similarly has a broader anterior notch and broader, shallower paired petals. It differs, however, from *P. maccoyi* in possessing a less deeply indented anterior notch.

Pericosmus celsus sp. nov.

Figures 7-9

Holotype

SAM P23823, from 'Murray River cliffs,' probably from the Early Miocene Longfordian Mannum Formation.

Paratype

NMV P18354 from the Mannum Formation at Mannum, South Australia.

Figure 7 *Pericosmus celsus* sp. nov.; SAM P23823, holotype, from the Murray River cliffs; probably Mannum Formation; aboral view; × 1.

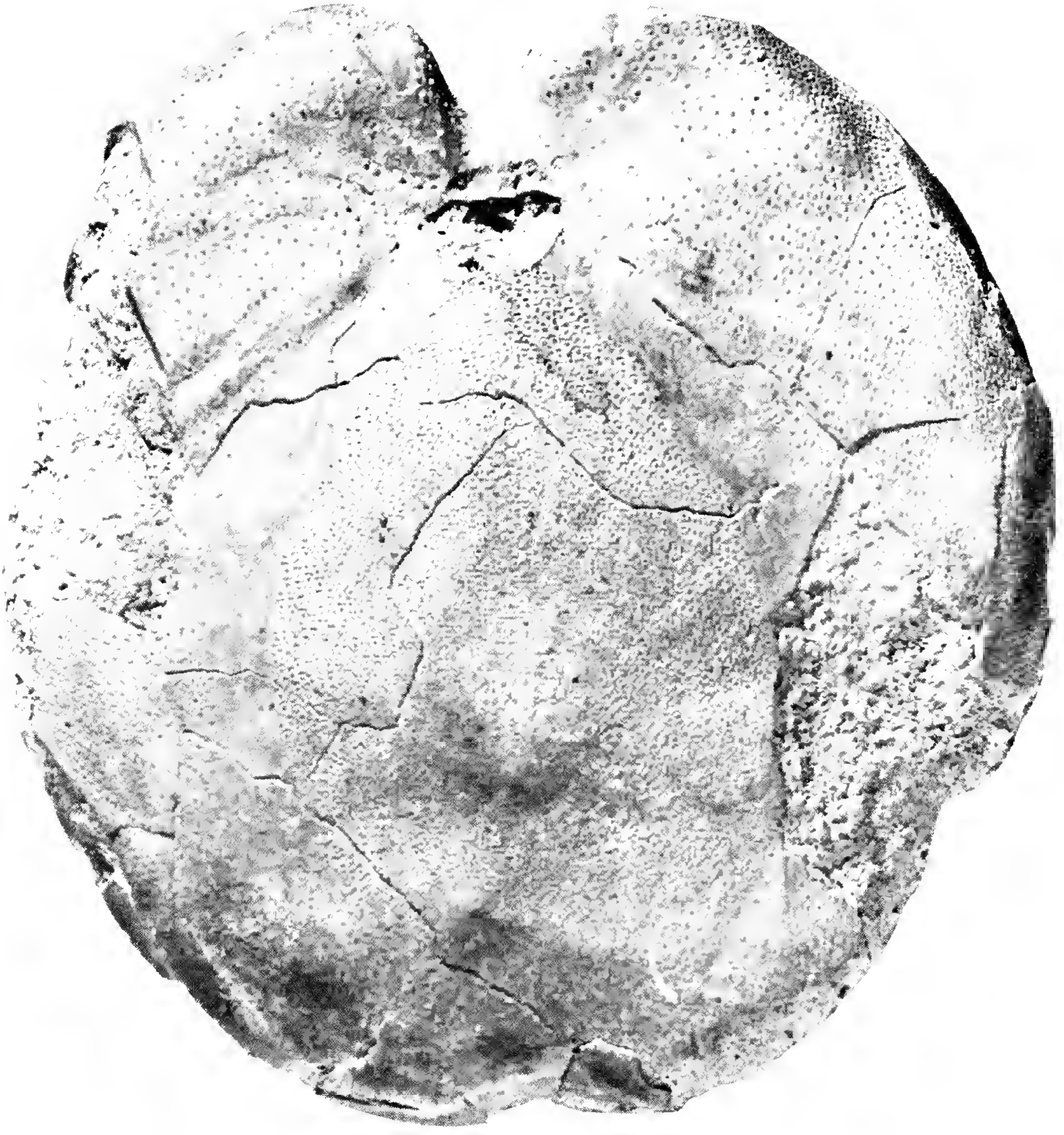

Figure 8 *Pericosmus celsus* sp. nov.; SAM P23823, holotype, from the Murray River cliffs; probably Mannum Formation; adoral view; × 1.

Diagnosis

Large species of *Pericosmus*, with vaulted test; interambulacra 1 and 4 most swollen adapically. Apical system positioned close to anterior ambitus. Petals long, deep and broad. Anterior petals widely divergent. Peristome sunken and relatively narrow. Plastron broad.

Description

Test large, reaching a maximum known length of 135 mm; width less than length; high, 52-56% TL. Anterior notch deep and quite broad (Figure 7). All interambulacra swollen adapically, but interambulacra 1 and 4 are the most tumid. Ambulacrum III moderately depressed. Petals long, deep and broad. Anterior paired petals diverge at about 40°; slightly shorter than posterior pair which occupy up to 34% TL; bear up to 40 pore pairs in each row. Posterior petals diverge at about 65° and possess up to 44 pore pairs in each row. Peripetalous fasciole weakly indented between anterior and posterior petals. Anterior branches plunge down interambulacra 2 and 3 to join marginal fasciole.

Peristome relatively narrow, 13-15% TL and sunken. Labrum projects moderately anteriorly. Plastron broad (Figure 8), 45-48% TL. Plates 1 and 2 of interambulacrum 1a in contact and not separated by second plate of 1b.

Remarks

P. celsus, which occurs in Longfordian strata, can be distinguished from *P. compressus* by its much higher test; its more anteriorly positioned apical system; more swollen lateral and anterior interambulacra (Figure 9), but much less swollen interambulacrum 5; the more steeply inclined anterior of the test; the longer paired petals; the less strongly anteriorly projecting labrum; and the broader plastron.

P. scaevus Henderson, 1975 from the Early Miocene of New Zealand also has a vaulted test and anteriorly positioned apical system, but *P. celsus* can be distinguished by the steeper anterior slope of the test, longer petals and more open anterior notch.

Etymology

Celsus (Latin) – high, lofty.

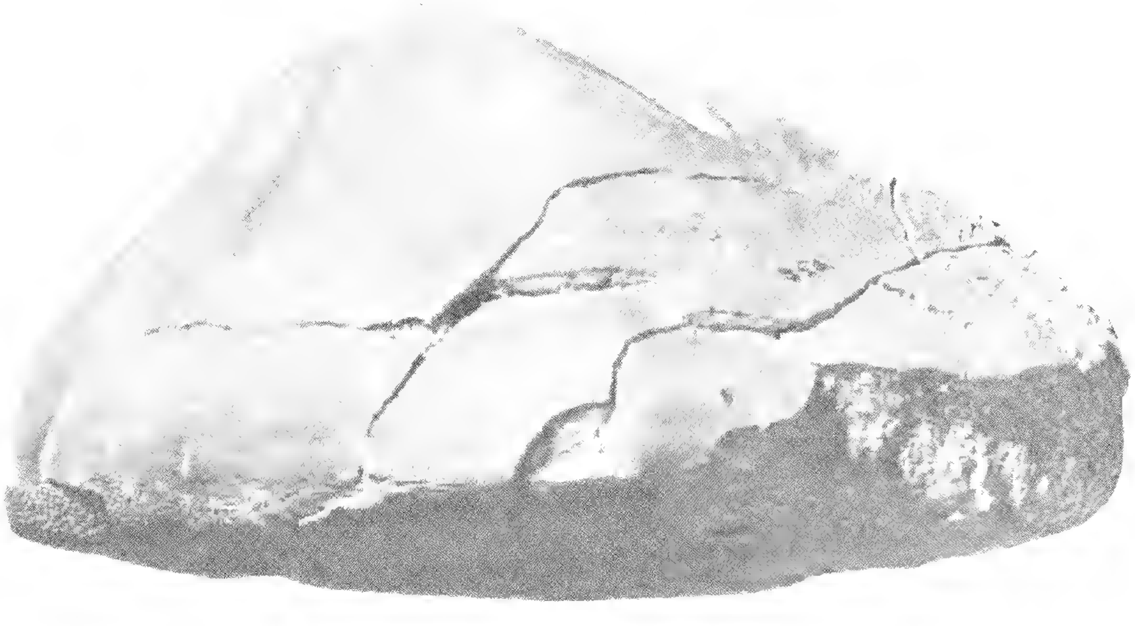

Figure 9 *Pericosmus celsus* sp. nov.; SAM P23823, holotype, from the Murray River cliffs; probably Mannum Formation; lateral view; × 1.

Pericosmus quasimodo sp. nov.

Figures 10-13

Holotype

NMV P55512 from 'Marble Arch, Port Campbell', from the Middle Miocene Bairnsdalian Rutledge Marl Member of the Port Campbell Limestone. Specimen collected by Mr George Baker.

Paratypes

NMV P55503, 55504 from the Port Campbell Limestone at the mouth of Ingles Creek, Port Campbell, Victoria.

Diagnosis

Test with very steep anterior slope and apex set anterior of apical system, as interambulacra 2 and 3 and ambulacrum III are very swollen adapically. Anterior notch very deep and narrow. Peristome deeply sunken. Labrum projecting very strongly anteriorly.

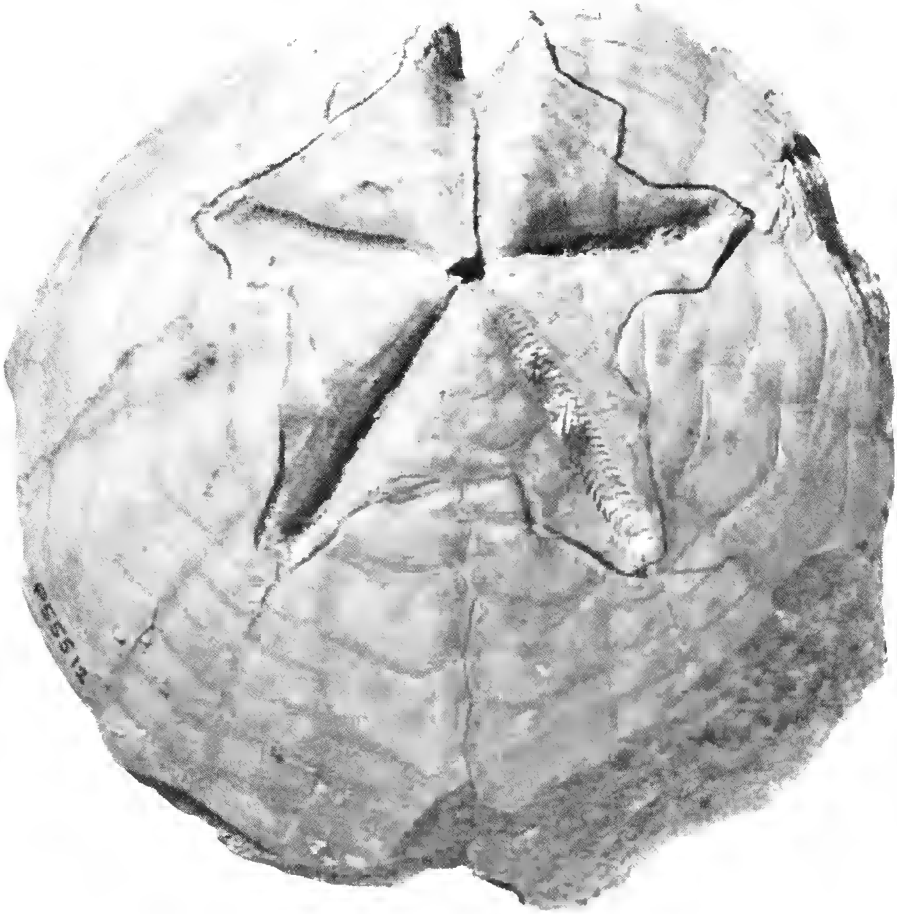

Figure 10 *Pericosmus quasimodo* sp. nov.; NMV P55512, holotype, from the Rutledge Marl Member of the Port Campbell Limestone at Port Campbell; aboral view; × 1.

Figure 11 *Pericosmus quasimodo* sp. nov.; NMV P55512, holotype, from the Rutledge Marl Member of the Port Campbell Limestone at Port Campbell; adoral view; × 1.

Description

Test large, reaching a maximum known length of 130 mm; high, 50-54% TL. Anterior notch very deep and narrow (Figure 11). Interambulacra 2 and 3, and ambulacrum III strongly swollen adapically (Figure 13B). Interambulacrum 5 forms a weak keel. Apical system set posterior of apex, and positioned 22-26% from anterior ambitus. Ambulacrum III shallow adapically, becoming deeply sunken abapically. Petals deep, narrow; relatively short in small specimens of test length 76 mm, occupying 25% TL; in holotype, which has a test length of 130 mm, they occupy up to 32% TL; posterior pair slightly longer. Anterior petals diverge at about 145° and have 25 pore pairs in each row in small specimen, 31 in large specimen. Posterior petals diverge at about 80°.

Peristome deeply sunken and set some distance back from anterior notch (18% TL). Labrum projects strongly forward (Figure 11), passing across peristome and slightly beyond it. Plastron relatively narrow, occupying 43-44% TL.

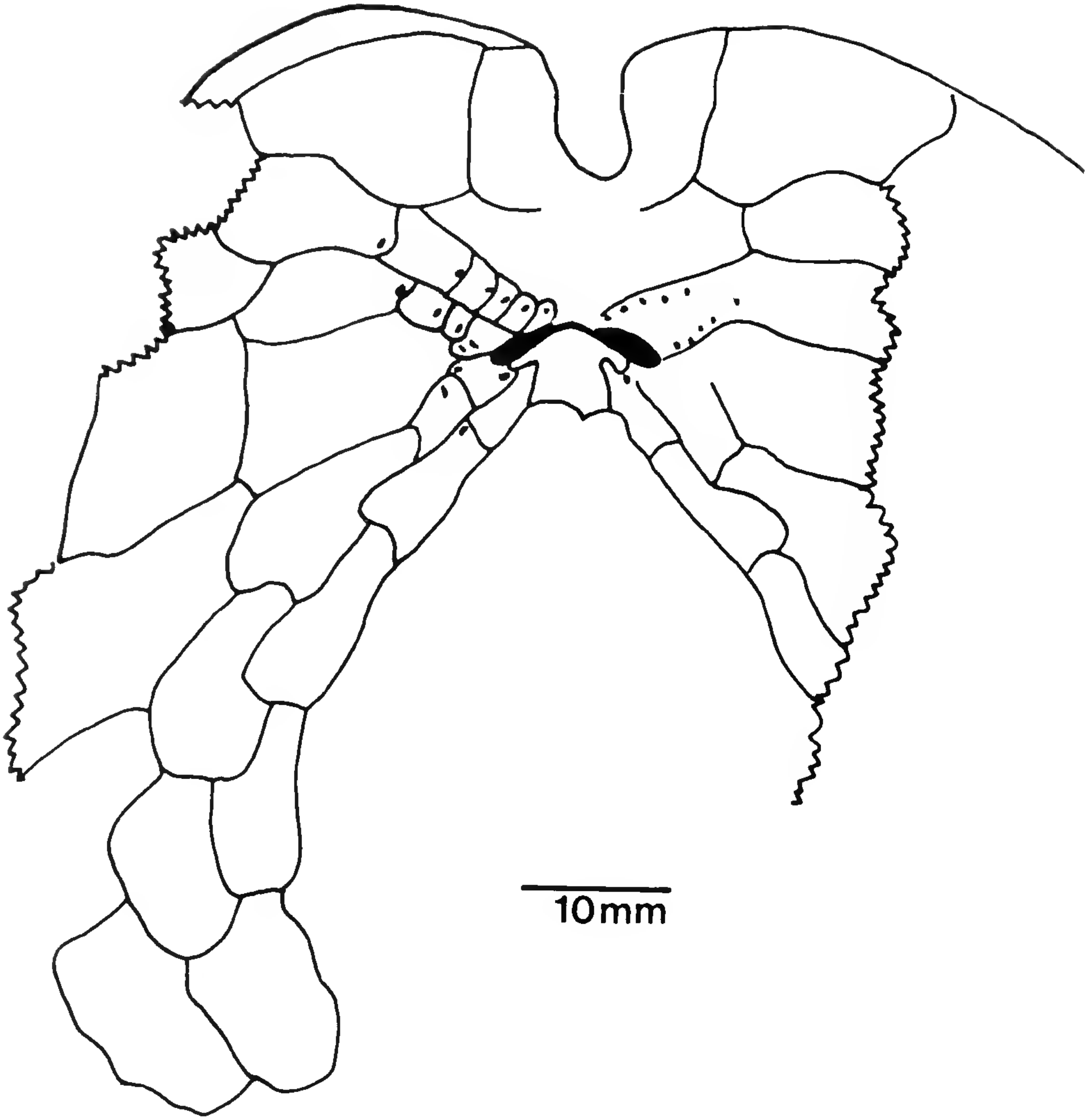

Figure 12 Adoral plating of holotype of *Pericosmus quasimodo* sp. nov., P55512.

Remarks

P. quasimodo is characterised mainly by the presence of a strongly developed 'hump' anterior to the apical system. This distinguishes it from the other vaulted species, *P. celsus*, in which the lateral interambulacra are more swollen adapically. *P. quasimodo* can also be distinguished by its slightly lower test; its shorter, straighter, narrower paired petals; the deeper anterior notch of large specimens; the more anteriorly positioned apical system; the more posteriorly positioned and deeper, more sunken peristome; the more anteriorly projecting labrum and the slightly narrower plastron.

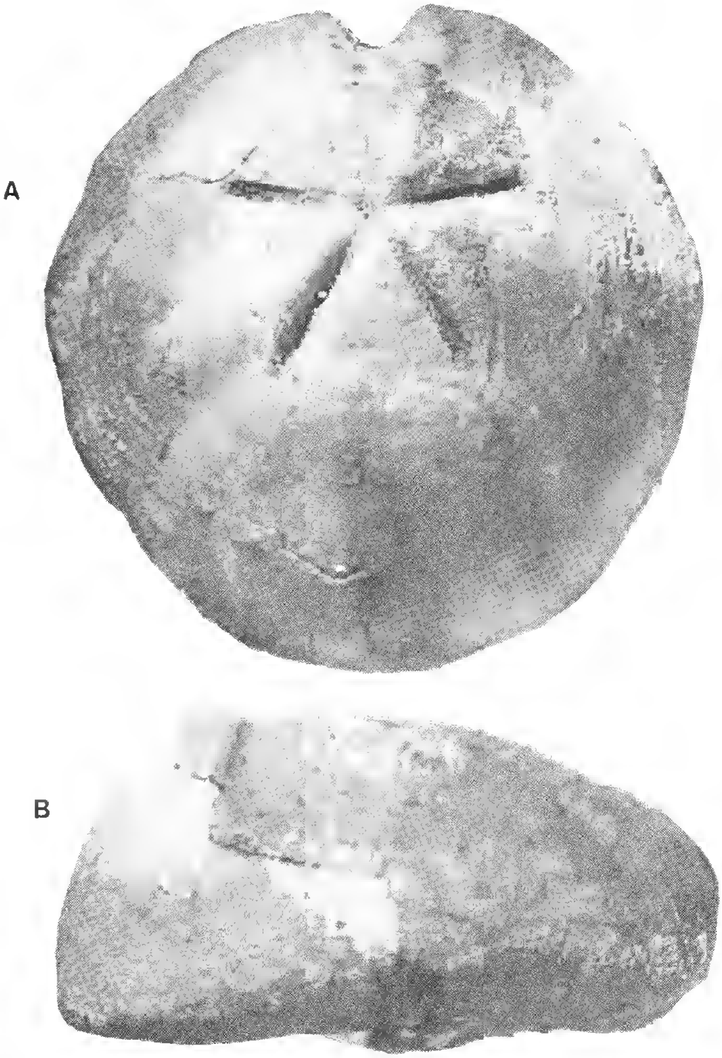

Figure 13 *Pericosmus quasimodo* sp. nov.; (A) aboral view and (B) lateral view of NMV P55504, from the Port Campbell Limestone at Port Campbell; both × 1.

The three type specimens show a size range from a test length of 77 mm to 130 mm. With growth the most discernable changes are a deepening of the anterior notch; the relative lengthening of the paired petals (from 24% TL to 29% TL for the anterior pair); a relative increase in length of posterior petals (from 25 to 33% TL) – the anterior and posterior petals are of similar length in small adults, whereas the posterior petals are longer in large adults; a slight deepening of the peristome and anterior lengthening of the labrum. These changes mirror ontogenetic changes which occurred in *P. compressus*.

Etymology

Quasimodo – the 'Hunchback of Notre Dame', alluding to the prominent hump on the aboral surface of the test.

Pericosmus torus sp. nov.

Figures 14-16

Holotype

NMV P20072 from the Longfordian to Batesfordian (Early to Middle Miocene), Batesford Limestone, Batesford, Victoria.

Paratypes

NMV P20071, 20073, 20074, 55502, 55505 from same horizon and locality as holotype.

Figure 14 *Pericosmus torus* sp. nov.; NMV P20072, holotype, from the Batesford Limestone at Batesford; aboral view; × 1.

Figure 15 *Pericosmus torus* sp. nov.; NMV P20072, holotype, from the Batesford Limestone at Batesford; adoral view; × 1.

Diagnosis

Test highest anterior of apical system, where anterior interambulacra 2 and 3 are slightly more swollen than interambulacra 1 and 4 adapically. Anterior notch deep and broad. Plastron broad, width more than half test length.

Description

Test large, reaching a maximum known length of 140 mm; high, 57% TL. Anterior notch deep and broad (Figure 14). Interambulacra all swollen adapically, interambulacra 2 and 3 being more swollen than 1 and 4; a weak keel present in interambulacrum 5. Apical system

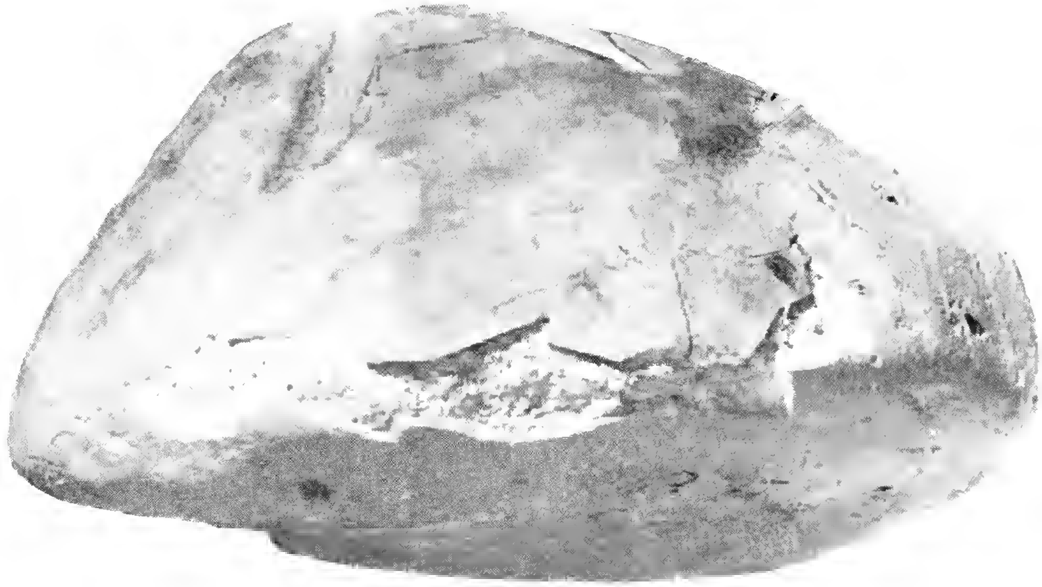

Figure 16 *Pericosmus torus* sp. nov.; NMV P20072, holotype, from the Batesford Limestone at Batesford; lateral view; × 1.

situated at 27% TL from anterior ambitus. Petals straight, deep; relatively longer in larger individuals, being only 20% TL in specimen of 100 mm TL, but 31% in specimen of 135 mm TL; up to 38 pore pairs in each row of posterior petals. Anterior petals diverge at about 145°; posterior at about 65°.

Peristome moderately sunken, width 14% TL. Plastron relatively broad (Figure 15), 52% TL.

Remarks

P. torus is intermediate both in morphology and in stratigraphic position between the older *P. celsus* and *P. quasimodo*. Like *P. celsus* it has long petals in large specimens and a deep, broad anterior notch. It differs from that species in having an anterior 'hump' due to swelling of interambulacra 2 and 3, and a broader plastron. It can be distinguished from *P. quasimodo* in having a less anteriorly eccentric apical system, a shallow ambulacrum III, a less pronounced anterior 'hump,' and a broader plastron. Like other species of *Pericosmus*, smaller adults have relatively shorter petals and the anterior ones are longer, unlike large specimens in wheih the posterior ones are longer.

Etymology

Torus (Latin) – protruberance.

Material, Locality and Horizon

An incomplete specimen (NMV P18037) from the Middle Miocene Morgan Limestone, 6 km below Morgan on the Murray River, South Australia.

Pericosmus sp. A
Figure 17

Description

Test relatively narrow and low (height 34% TL). Apical system anteriorly situated at 30% TL. Paired petals deep and narrow, with 28 pore pairs in anterior and posterior pairs; 25-27% TL. Ambulacrum III shallow adapically, becoming very deep abapically. Anterior notch deep and narrow (Figure 17A). Interambulacra 2 and 3 swollen such that the highest point of test is anterior to apical system. Peripetalous fasciole joining marginal fasciole anteriorly. Peristome moderately sunken; width 14% TL. Labrum gently arched anteriorly to reach half way across peristome (Figure 17B).

Remarks

The low test of this form is reminiscent of *P. compressus* and *P. maccoyi*, but its more anteriorly positioned apical system, deep, narrow anterior notch and swollen interambulacra distinguish it. In these features it compares with *P. quasimodo* but it differs in the much flatter test, the relatively shorter anterior petals and the less anteriorly projecting labrum. It is not unlike *P. crawfordi*, but it has a deeper anterior notch and more swollen anterior interambulacra.

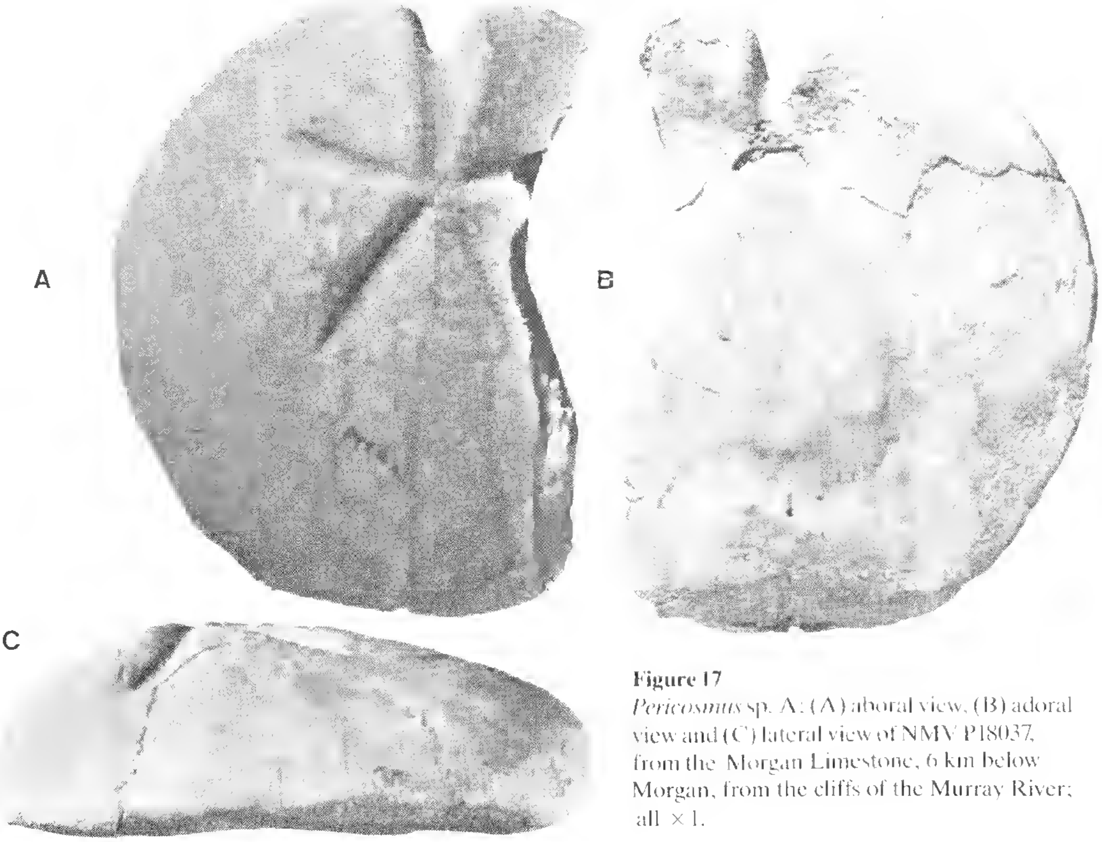

Figure 17
Pericosmus sp. A: (A) aboral view, (B) adoral view and (C) lateral view of NMV P18037, from the Morgan Limestone, 6 km below Morgan, from the cliffs of the Murray River; all × 1.

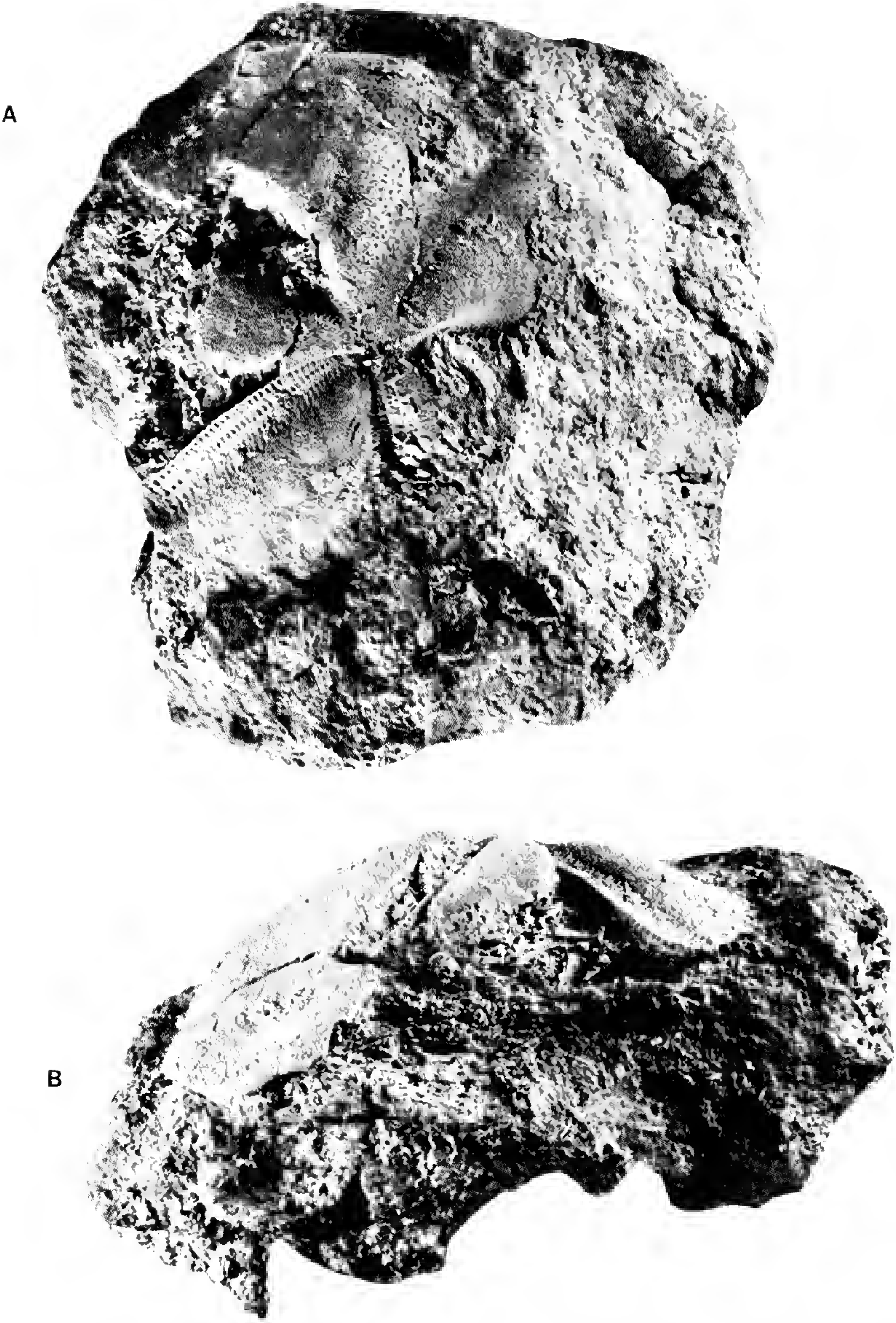

Figure 18 *Pericosmus* sp. B (A) aboral view and (B) lateral view of WAM 82.1661, from the Tulki Limestone, Cape Range; both ×0.90.

Pericosmus sp. B

Figure 18

Material, Locality and Horizon

Two incomplete specimens, WAM 82.1661 and 82.1673, from the Early Miocene Tulki Limestone, from the Cape Range, Western Australia: a ridge 1 km south of Charles Knife Road.

Description

Test large, vaulted; length not known, but probably about 110 mm. All interambulacra swollen adapically to some degree. Interambulacrum 5 most inflated, forming a prominent keel. Interambulacra 2 and 3 more swollen than 1 and 4. Petals short, shallow and broad, posterior petals bearing about 36 pore pairs in each row. Anterior petals diverge at about 130°, posterior at about 70°. Adoral surface unknown.

Remarks

Pericosmus sp. B is closest to the penecontemporaneous *P. compressus*. However, it differs in its possession of a more vaulted test, shallower, broader petals and more swollen interambulacra 2 and 3. In lateral profile *P.* sp. B bears some similarity to *P. torus* but it has a more posteriorly positioned apical system and consequently less divergent anterior petals.

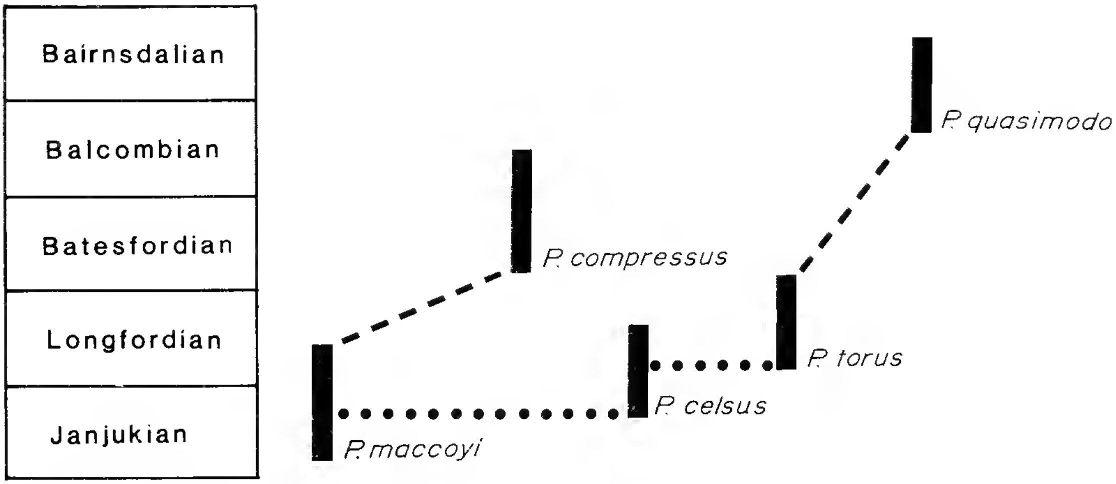

Figure 19 Stratigraphic ranges of the named species of *Pericosmus*, and suggested phylogenetic relationships.

Family Schizasteridae Lambert, 1905

Genus *Waurnia* gen. nov.

Types Species

Pericosmus nelsoni McCoy, 1882: 17.

Diagnosis

Test large, ovoid, with faint anterior notch. Peripetalous and lateroanal fascioles present. Apical system ethmolytic, with four genital pores; anteriorly very eccentric, less than one-fifth test length from anterior. Paired petals almost flush with test. Anterior pair long, extending to ambitus; posterior pair shorter, but pore pairs continuing between peripetalous and lateroanal fascioles, diminishing in size abapically. Labrum short, anteriorly projecting. Periproct longitudinally oval and large.

Remarks

McCoy (1882) originally placed this species in *Pericosmus* because of the nature of the fasciole which has a lateroanal course close to the ambitus, reminiscent of the marginal fasciole in *Pericosmus*. However, junction of the peripetalous fasciole with this lateral fascile in interambulacra 1 and 4 shows that it is a lateroanal fasciole and not a marginal fasciole, as McCoy supposed. Like *Prenaster*, the peripetalous fasciole extends around the anterior of the test below the ambitus. *Waurnia* is similar to *Prenaster* in its possession of paired petals almost flush with the test, and a very anteriorly eccentric apical system. However, *Waurnia* can be distinguished by its much larger size, having pore pairs continue beyond the posterior petals, the anterior paired petals being longer, and the much larger periproct. The size and shape of the test and petal arrangement are reminiscent of *Pseudobrissus*, but in that genus the paired petals are deeply depressed. *Brissomorpha* from the Miocene of Austria, Algeria and Indonesia has a superficial similarity to *Waurnia*, particularly in its large, depressed periproct. Although the question of whether or not *Brissomorpha* has any fascioles other than a peripetalous fasciole is unknown, its more widely spaced pore pairs in the paired petals and the apparent absence of ambulacral pores beyond the petals distinguish the two genera. The only other spatangoid in which pore pairs continue beyond the peripetalous fasciole is the brissid *Gaulteria*. Lambert (1905: 158) considered that *Pericosmus nelsoni* might best be placed in *Peribrissus*. However this genus differs from *Waurnia* in possessing a deep anterior notch and ambulacrum III; deeper, shorter petals; and flatter test.

Waurnia nelsoni (McCoy, 1882)

Figures 20-23

Pericosmus nelsoni McCoy, 1882: 17-19, Pl. 66, Figs 1, 2, Pl. 67, Fig. 1; Lambert 1905: 158.
Linthia nelsoni Pritchard 1908: 399; H.L. Clark 1946: 366; Gill 1952: 1-3, Fig. 1.
Prenaster nelsoni Lambert & Thiery 1924: 515.

Lectotype

Herein selected. NMV P12211 from the Janjukian (Late Oligocene) Waurn Ponds Limestone at Waurn Ponds, Victoria; Figured by McCoy 1882, Pl. 66, figs 1, 2 and Pl. 67, fig. 1.

Paralectotypes

NMV P12212, 12213 from the same locality and horizon as the lectotype.

Other Material

Twenty one other specimens from the same horizon and locality as the type material: NMV P4775, 19988, 19990, 19998, 26516, 63058-63063, 63065-63074. The locality at Waurn Ponds is a quarry 'on reserve opposite old "Victoria Inn," Colac Road, 5' miles from Barwon Bridge' (Gill 1952).

Diagnosis

As for generic diagnosis.

Figure 20 *Waurnia nelsoni* (McCoy, 1882); (A) aboral view and (B) lateral view of NMV P26516, from the Waurn Ponds Limestone at Waurn Ponds; both ×1.

Figure 21 *Waurnia nelsoni* (McCoy, 1882); adoral views of (A) NMV P12211, lectotype, and (B) NMV P12213, paralectotype; both from the Waurn Ponds Limestone at Waurn Ponds; both × 1.

Description

Test large, reaching a maximum known length of 140 mm; elongate, width 83-86% TL; high (up to 65% TL), highest at mid point, or slightly posterior of centre in interambulacrum 5, which is swollen to form low keel; other interambulacra not swollen aborally. Apical system anteriorly eccentric (Figure 20A) at only one-fifth test length from anterior; flush with test. Ambulacrum III very slightly depressed and forming faint anterior notch; very narrow and bearing extremely small pore pairs, with pores aligned almost exsagittally;

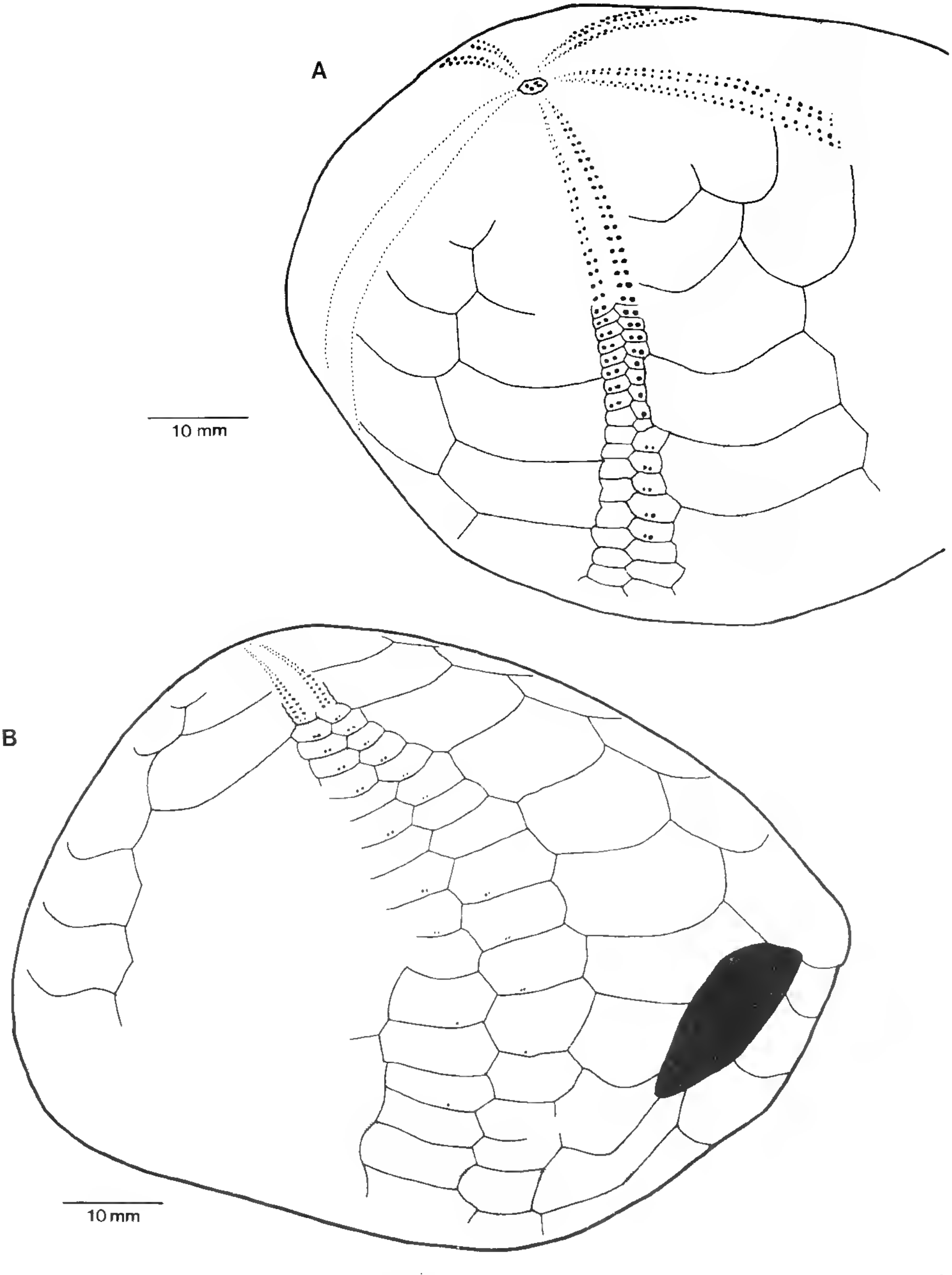

Figure 22 Drawings of plates, course of the fascioles and distribution of pore pairs in *Waurnia nelsoni* (McCoy, 1882); NMV P63072, (A) oblique antero-lateral view of aboral surface and (B) oblique postero-lateral view of aboral surface – note persistence of pore pairs between peripetalous and lateroanal fascioles.

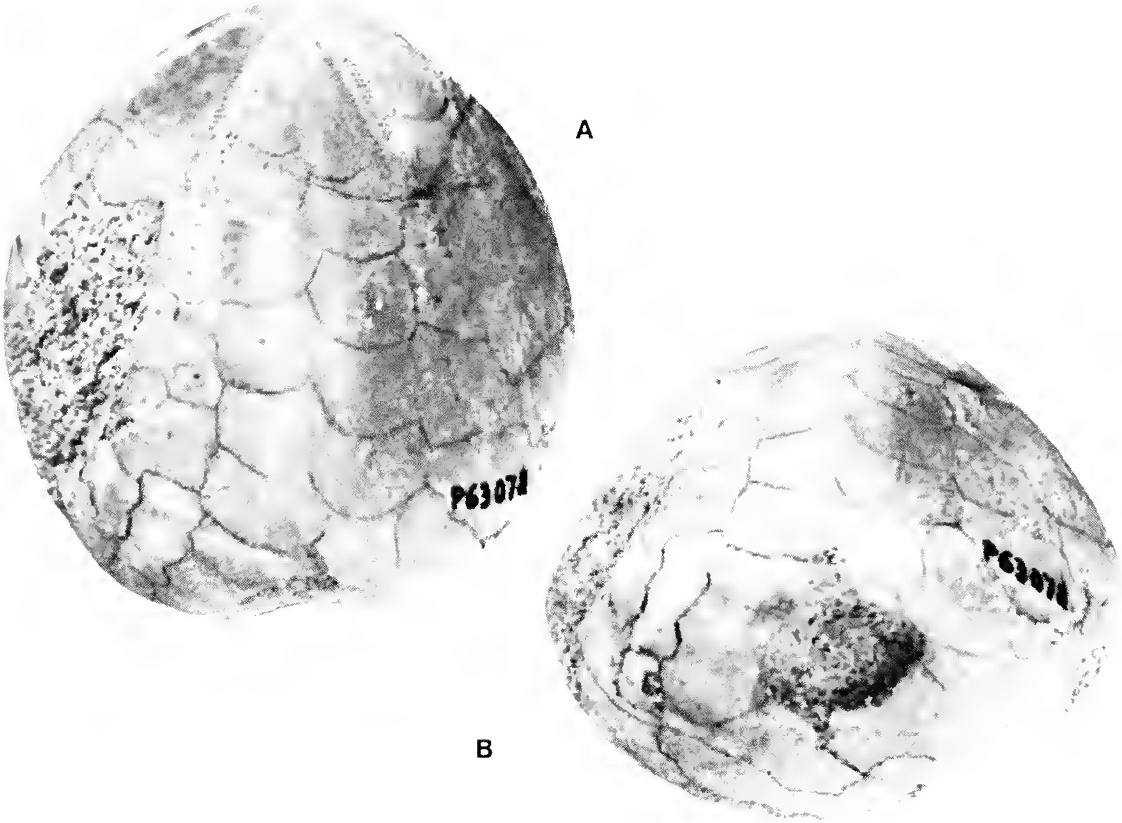

Figure 23 *Waurnia nelsoni* (McCoy, 1882): (A) oblique view of posterior of aboral surface of test and (B) posterior view of test, showing large periproct, of NMV P63072, both × 1.

ambulacral plates bearing much smaller tubercles than occur on adjoining interambulacral plates. Paired petals narrow and flush to slightly impressed. Orientation of anterior pair varies between an angle of a little less to a little more than 180°. Inner pores almost circular to slightly ovoid; outer pores round to tear-shaped; neither sunken nor conjugate. Anterior and posterior rows diverge slightly abapically; about 40 pore pairs in each row, extending to the ambitus. Posterior petals diverge at about 60°. Pore pairs closely spaced between peripetalous fasciole and apical system (Figures 22B, 23A), where they extend for a distance equal to about 33% TL; pore pairs continue between peripetalous and lateroanal fascioles (Figures 22B, 23A) and are more widely spaced and diminish in size toward ambitus, which they reach postero-laterally. About 32 pore pairs up to peripetalous fasciole and a further 12 between the fascioles. Lateroanal fasciole marginal in lateral interambulacra. Met by peripetalous fasciole close to ambitus. Anteriorly peripetalous fasciole runs marginally, just below ambitus.

Anterior of peristome positioned 14-18% TL from anterior ambitus; sunken, lunate, broad, 18% TL. Labrum short, but projecting strongly anteriorly across peristome (Figure

21B). Phyllode with unipores, 8 in ambulacrum III, 12 in ambulacra II and IV, and 8 in ambulacra I and V. Plastron moderately convex; large, width up to 45% TL. Second plate of interambulacrum 1b does not extend to ambulacrum I, only abutting ambulacrum II. Interambulacral areas covered by densely packed, large tubercles. Interambulacrum 5 overhangs periproct posteriorly. Periproct oval, large (Figure 23B), with long axis up to 18% TL. Subanal area slightly depressed.

Remarks

The species description is based largely on topotype material as McCoy's (1882) syntypes are poorly preserved specimens. *W. nelsoni* is well known from Waurn Ponds where it occurs in Janjukian strata. McCoy (1882) records that it occurred in abundance in one particular bed in the old Waurn Ponds quarries, near the base of the section. The specimens occurred in a nodular limestone band, with the lower parts of the test resting on softer marl beneath.

Gill (1952) described a specimen (NMV P15277) of *W. nelsoni* which he believed to be unique in bearing spines. Ten of the specimens studied herein (NMV P4775, 19998, 26516, 63061, 63062, 63065, 63068, 63072-4) bear adoral spines, either on the plastron or on the lateral interambulacra. This, together with their field occurrence, suggests they lived buried in the sediment and died in this position. As the test was not exposed after death, many of the spines remained to be fossilized *in situ*.

Genus *Victoriaster* Lambert, 1920

Type Species

Pericosmus gigas McCoy, 1882: 15; by original designation.

Diagnosis

Test very large size with very deep anterior notch. Pore pairs in ambulacrum III very small. Paired petals long, deep and quite narrow. Peripetalous and lateroanal fascioles present. Peristome deeply sunken with labrum strongly anteriorly projecting.

Remarks

Victoriaster was considered by Mortensen (1951: 169) to be synonymous with *Pericosmus*, and by Fischer (1966) to be a subgenus of *Pericosmus*. Clearly, it is not related to *Pericosmus* as it does not possess a marginal fasciole, but has a lateroanal fasciole. The genus therefore does not belong in the Pericosmidae. *Victoriaster* is most closely related to *Linthia*, in which the type species was placed by Pritchard (1908) and H.L. Clark (1946). However, it can be distinguished by its larger size (specimens attaining a length of 220 mm); its very deep anterior notch; its much reduced pore pairs in ambulacrum III; its long, deep and rather narrow paired petals; and a strongly anteriorly projecting labrum.

Victoriaster gigas (McCoy, 1882)

Figures 24-27

Pericosmus gigas McCoy 1882: 15-16, Pls. 64, 65; Tate 1891: 277; Mortensen 1951: 170-171, Fig. 80.
Linthia gigas – Pritchard 1908: 396; H.L. Clark 1946: 365.
Linthia mooraboolensis Pritchard, 1908: 384, Pls 22,23; H.L. Clark 1946: 366.
Victoriaster gigas – Lambert 1920: 27, Lambert & Thiéry 1924: 573.

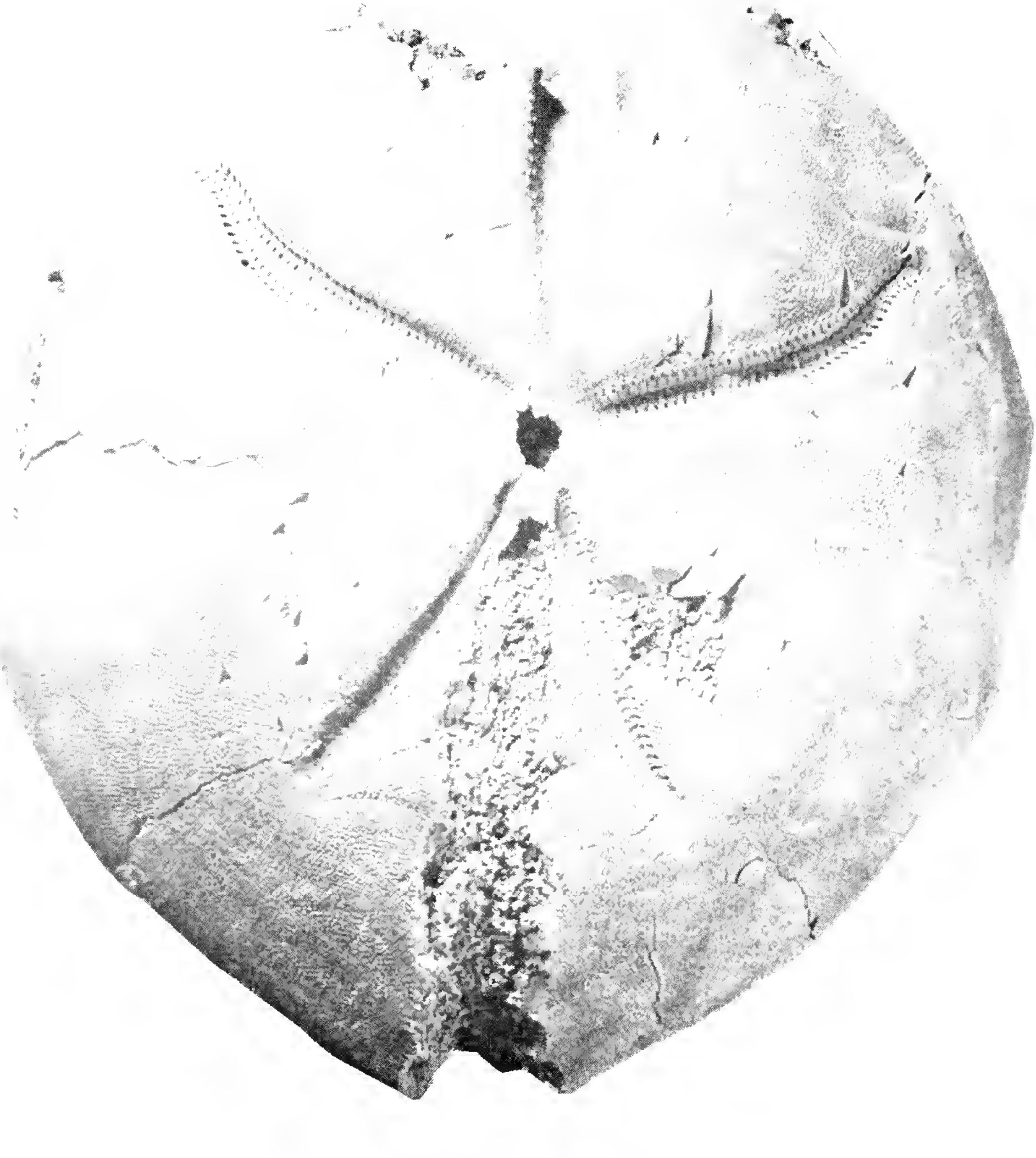

Figure 24 *Victoriaster gigas* (McCoy, 1882): NMV P4833, holotype, from the Batesford Limestone at Batesford; aboral view; × 0.75.

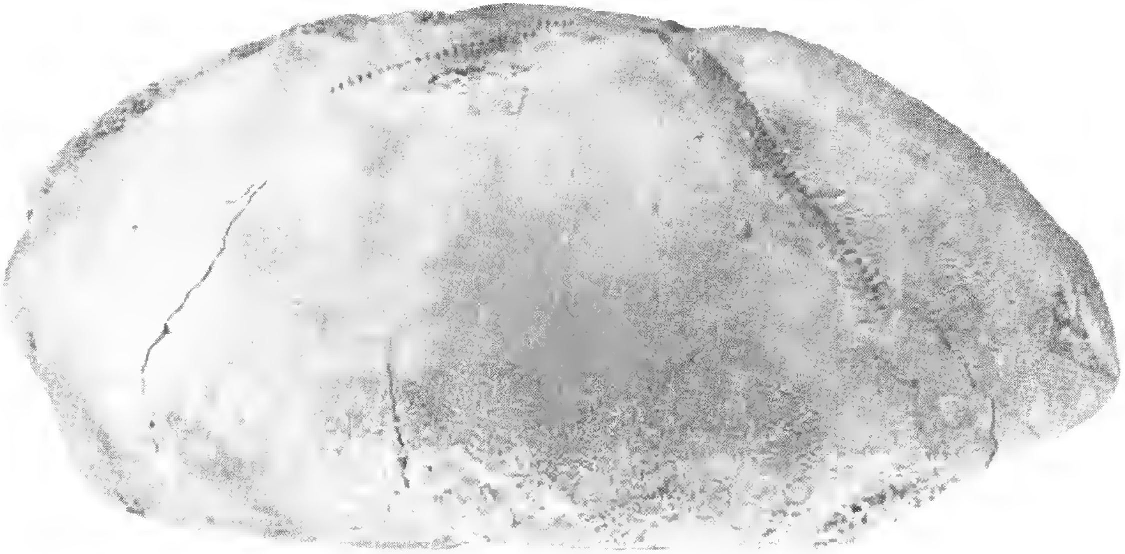

Figure 25 *Victoriaster gigas* (McCoy, 1882); NMV P4833, holotype, from the Batesford Limestone at Batesford; lateral view; ×0.75.

Material and Horizon

The holotype (by monotypy) is NMV P4833. Pritchard (1908) questioned the correctness of the localities originally given by McCoy ('on bank of Murray, near Junction with Darling, and in similar strata of Corio Bay'). He concluded that McCoy's material came from the Batesford Limestone. However, Dr T.A. Darragh of the Museum of Victoria, has recently discovered (Darragh, litt. comm. 26.10.83) that the holotype was given to William Blandowski, Zoologist and Collector of the National Museum of Victoria, when he was leading the Murray-Darling Expedition in 1857. The specimen was collected by Mr T.H. Wigley. It was originally registered as No. 2491 in the list of specimens obtained on the Expedition. A drawing of the specimen by Blandowski has been obtained by Dr Darragh. On it is recorded 'Longit. 140 Lat. 34°', placing the specimen on the Murray River near Waikerie. Therefore although Pritchard (1908) was correct to question the locality given by McCoy (1882), he was in error in believing that the specimen came from the Batesford Limestone. It is almost certainly from the contemporaneous Morgan Limestone.

Apart from the holotype and one incomplete specimen from Grange Burn (i.e. the Hamilton Beds of Balcombian age), the Batesford Limestone is the only horizon from where the species has been collected. Specimens from this horizon are: NMV P20075, 27028, 78027-9, 78031, 78034, 78035, 78039-41, 78060, 78063, MUGD 1080, 1689.

Diagnosis

As for genus.

Description

Test very large, up to 220 mm long; subcircular in plan view, width only slightly less than length. Test high, reaching almost 50% TL (Figure 25); apex in swollen interambulacrum 5 just posterior of apical system. Apical system anteriorly eccentric at 45% TL from anterior ambitus; bearing four genital pores. Anterior notch deep, 11% TL (Figure 26); relatively broad. Ambulacrum III shallow adapically, deepening abruptly at one-third ambulacral length. Pore pairs minute, widely spaced. Floor of ambulacrum covered only by small miliary tubercles; side walls with relatively large (1 mm diameter), scattered tubercles.

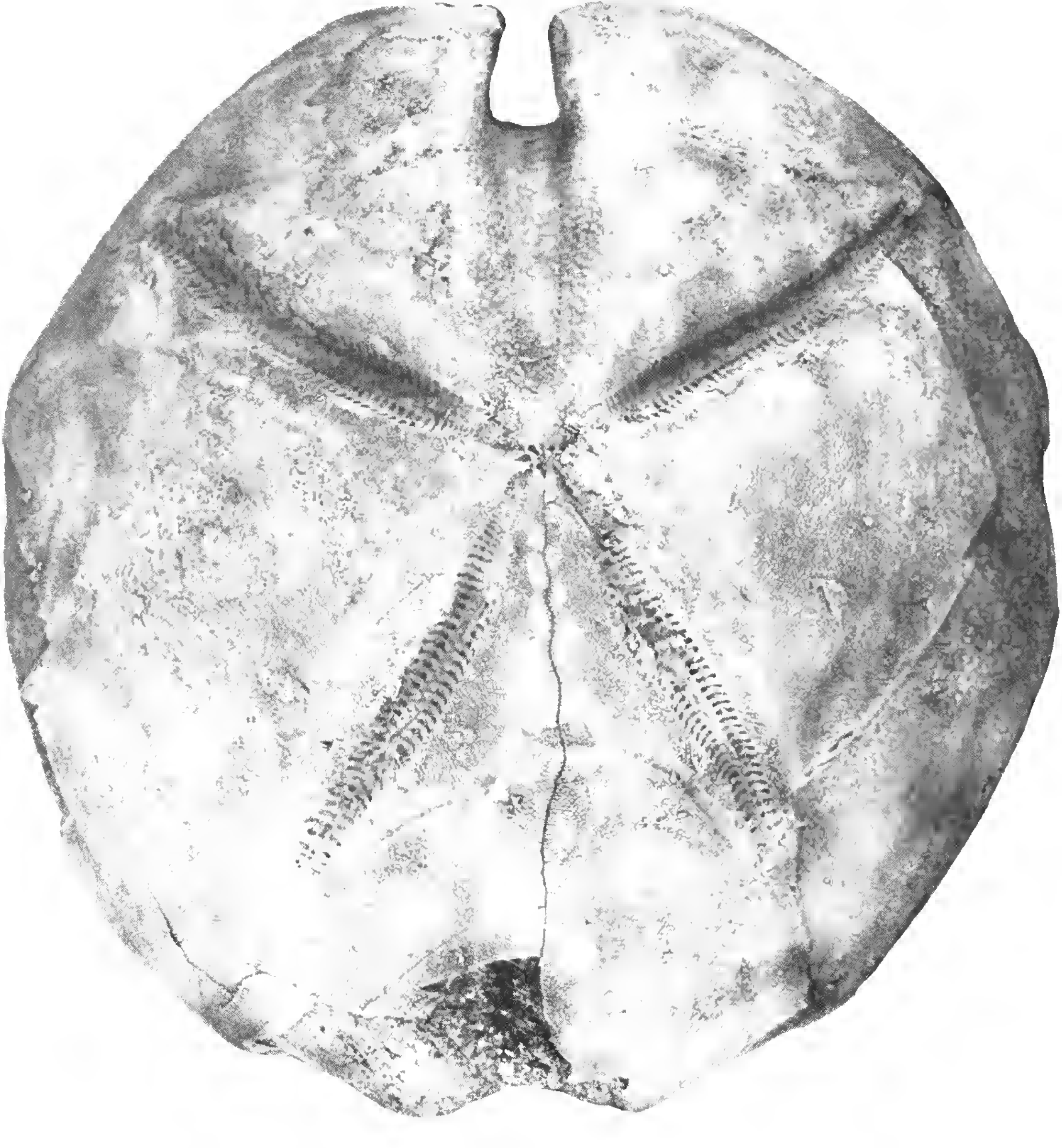

Figure 26 *Victoriaster gigas* (McCoy, 1882): MUGD 1080, from the Batesford Limestone at Batesford; aboral view; × 0.64.

Anterior petals diverge anteriorly at about 135°, almost straight, but flex slightly anteriorly at three-quarters petal length; deep, but relatively broad, width 5% TL; holotype bearing 47 non-conjugate pore pairs. Posterior petals almost straight and diverge at 60°; slightly longer than anterior; about 40% TL; similar width to anterior petals. Peripetalous fasciole following an erratic course, approaching only to within 18% TL of apical system in lateral

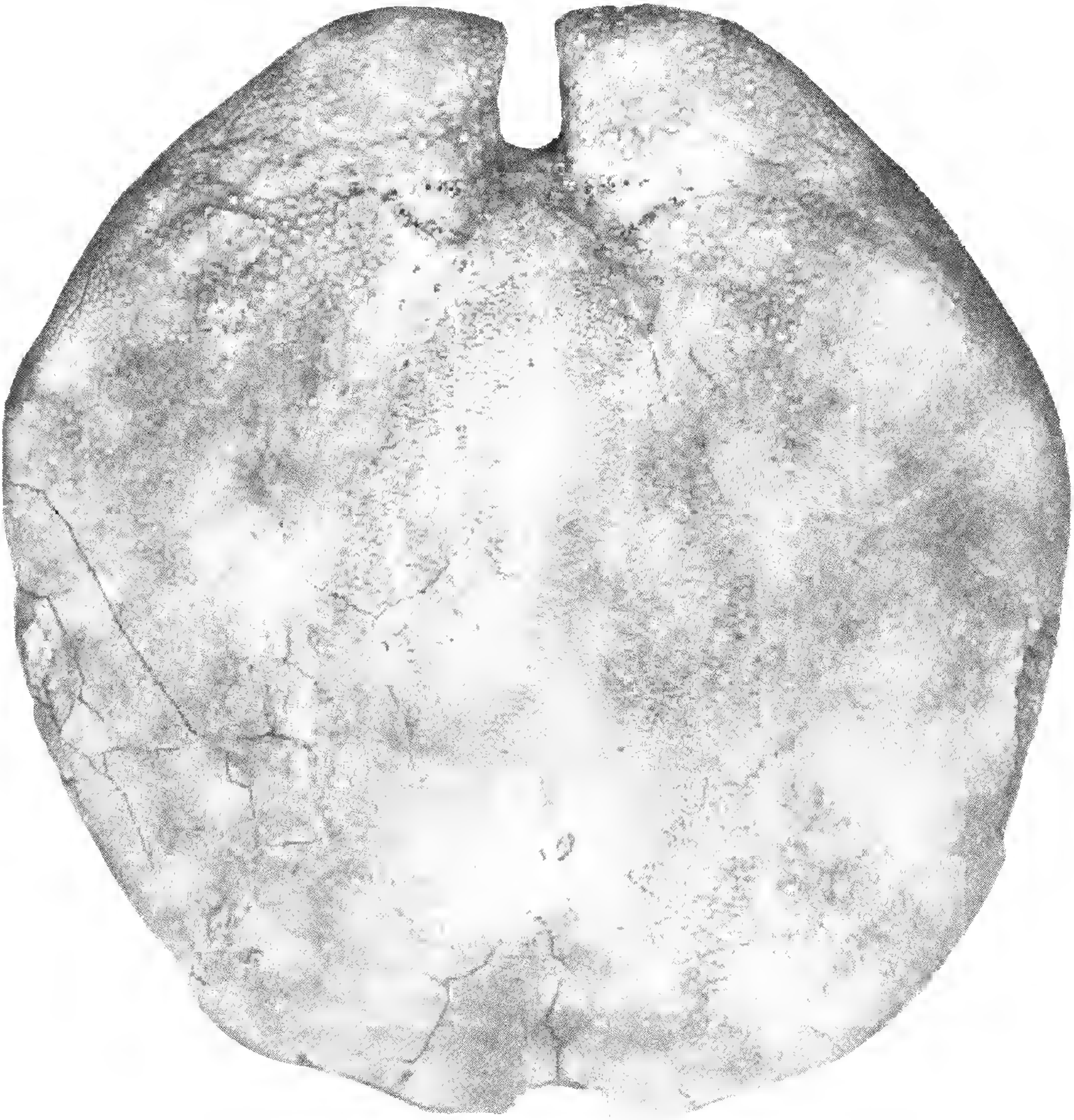

Figure 27 *Victoriaster gigas* (McCoy, 1882); MUGD 1080, from the Batesford Limestone at Batesford; adoral view; ×0.64.

interambulacra. On holotype lateroanal fasciole incomplete: extending posteriorly from peripetalous fasciole for short distance, then disappearing laterally; present posterolaterally. On other specimens (e.g. MUGD 1080 and 1689) it is entire.

Peristome small and sunken; width only 11% TL. Covered entirely by labrum which projects strongly forward (Figure 27). Pores in phyllode both unipores and anisopores; 14 in ambulacra II and IV; 7 in I, III and V. Plastron width 40% TL. Periplastronal width up to 10% TL. Plastron densely tuberculated with relatively small tubercles. Tubercles on other oral interambulacra almost twice as large (up to 30 mm diameter) and more widely spaced.

Remarks

V. gigas is probably the largest of all non-flexible echinoids ever to have lived. The largest known specimen has a length of 220 mm, a width of 205 mm and a height of 110 mm. It thus had twice the bulk of the giant living spatangoid *Plagiobrissus grandis* (Gmelin), the largest of which measured 220 × 165 × 55 mm (Mortensen 1951: 498).

Pritchard (1908) described a single specimen (MUGD 1689), which he called *Linthia mooraboolensis*, also from the Batesford Limestone. The main feature which distinguishes this specimen from the holotype of *V. gigas*, is its much lower test. The broken and dislocated nature of the interambulacral plates around the ambitus indicates that the lower profile is a product of post-depositional compaction. The specimen does possess slightly narrower petals and anterior notch than the holotype of *V. gigas*, but these differences are attributed to intraspecific variation. This is borne out by the character of the largest known specimen of *V. gigas*, MUGD 1080, which differs from the holotype of *V. gigas* in having longer and broader petals. Similar wide intraspecific variation is typical of the larger spatangoid echinoids, occurring also in living species of *Brissus* and *Breynia* (McNamara 1982).

Henderson (1975: 24) preferred to place Pritchard's *Linthia mooraboolensis* in *Lambertona*, but the type species of this genus, *L. lamberti* Sánchez Roig, 1953, is reported as possessing a thin, incomplete marginal fasciole Fischer (1966). *Lambertona lyoni* (Hutton, 1873), which Henderson (1975: 25) redescribed, has only a peripetalous fasciole. Kier (1984) has recently redescribed *L. lamberti*. He reports that this species of *Lambertona*, like *L. lyoni*, has neither a marginal nor a lateroanal fasciole, possessing only a peripetalous fasciole. The holotype of *Linthia mooraboolensis* possesses an entire lateroanal fasciole and, as noted above, is synonymous with *Victoriaster gigas*.

Phylogenetic Relationships of Australian Species of *Pericosmus*

The earliest species of *Pericosmus* to occur in the southern Australian Tertiary, *P. maccoyi*, possesses a relatively low test, subcentral apical system, and shallow to moderately deep petals. The later species, *P. compressus*, *P. celsus*, *P. torus*, *P. quasimodo* (Figure 19) and *P.* sp. B are typified by the possession of more highly vaulted tests (Figure 28); more anteriorly positioned apical systems; deeper petals; more sunken peristomes; more anteriorly projecting labra; and broader plastrons.

The earliest species of *Pericosmus*, such as *P. clarki* Lambert, 1933 from the Paleocene of Madagascar and *P. annosus* from the Eocene of New Zealand, have features more in common with the earliest (Late Oligocene) Australian species. There appears to have been a trend, during the Tertiary, for the periodic development of a smaller number of species which possess a larger test, deeper petals, more anteriorly positioned apical systems, elongate labra, and broad plastrons. However, the ancestral, early Tertiary, morphology appears to have persisted throughout the Tertiary to the present day, while the forms which

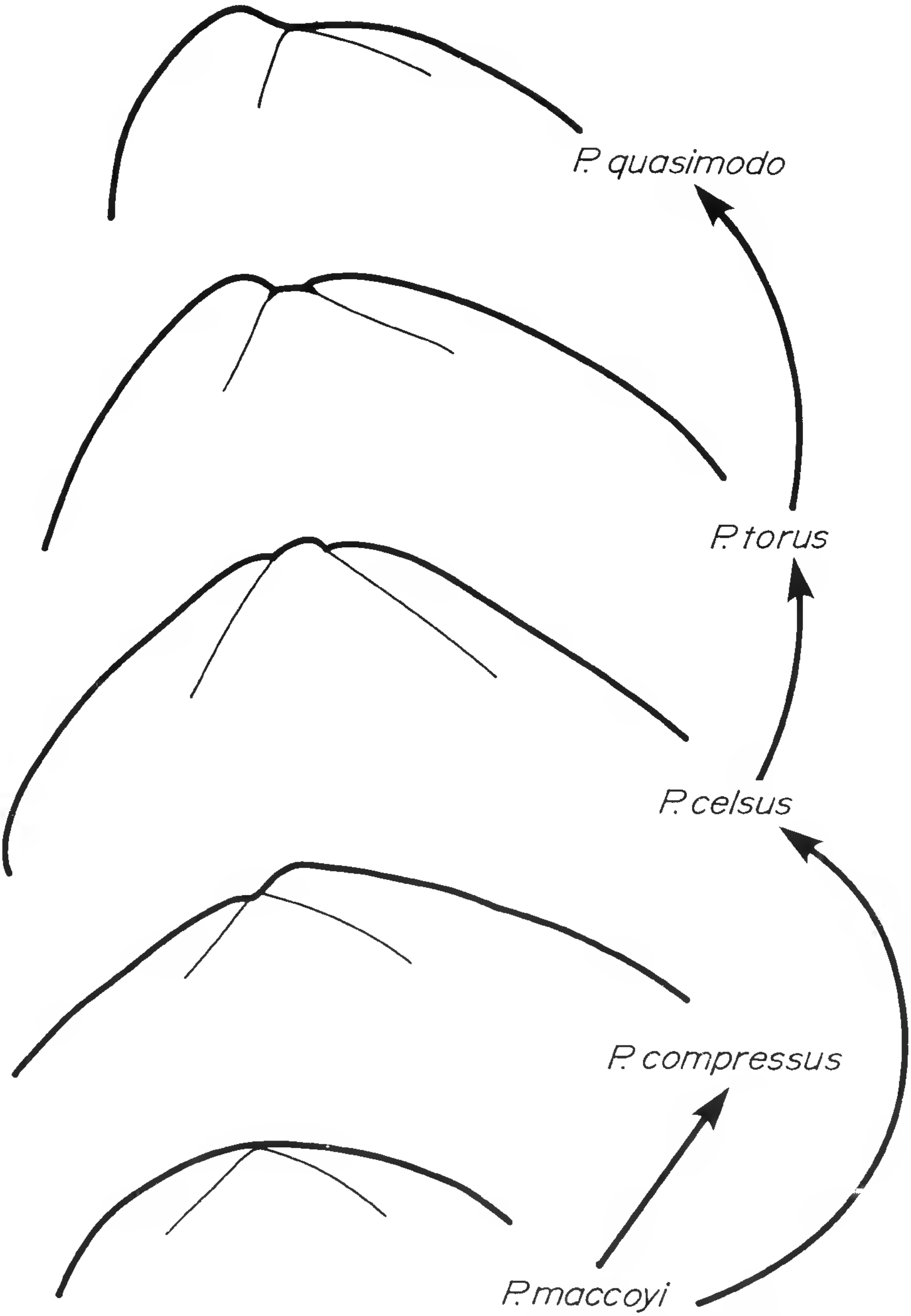

Figure 28 Drawings of lateral profiles of named species of *Pericosmus*, illustrating the general trend of development and anterior progression of adapical interambulacral swelling.

developed a highly vaulted test developed as short-ranging, iterative offshoots from the main *Pericosmus* stock. A recently discovered species, *Pericosmus porphyrocardius* from north-western Australia (McNamara 1984) is morphologically similar to the earliest Australian fossil species, *P. maccoyi*.

The phylogenetically early characters, associated with a low test, occur in small specimens of later species. In other words later species with vaulted tests, undergo greater morphological changes through ontogeny than their ancestors: they may be said to be peramorphic (Alberch *et al*. 1979). Thus, for instance, a small test of *P. compressus* resembles the largest specimens of earlier species in possessing shallow petals and a more open, shallow anterior notch; shorter petals than in large specimens; a more central apical system; a shallower peristome and a less anteriorly protruberent labrum. Growth within these Australian Late Oligocene-Early Miocene species, and later phylogenetic development within the Australian Miocene species, seems to have favoured a deepening of the petals and swelling of the intervening interambulacra; the anterior movement of the apical system and consequent development of a steeper anterior slope of the test; a deepening of the peristome and anterior lengthening of the labrum; and broadening of the plastron. Forms which developed these morphological characteristics are also larger than those species possessing ancestral morphology. These morphological changes may therefore have been brought about by hypermorphosis: delay in onset of maturity allowing continuation of morphological development beyond that of the ancestor. Delay in onset of maturity will also result in attainment of a larger size.

The Australian species show a trend of varying swelling of the aboral interambulacra adapically, from no swelling in the early *P. maccoyi* to swollen posterior interambulacrum in *P. compressus* and *P.* sp. B: swollen lateral interambulacra in the Longfordian *P. celsus;* swollen lateral and slightly swollen anterior interambulacra in the younger Longfordian-Batesfordian *P. torus;* and finally, only a strongly swollen, anterior interambulacrum in the latest species, the Bairnsdalian *P. quasimodo*. This anterior shift of swollen interambulacra accompanies an anterior shift in position of the apical system and increasing angle of declination of anterior of the test.

Functional interpretation of morphological changes.

Some of the evolutionary changes which occur within the spatangoid *Schizaster*, from the subgeneric morphotype *Paraster* to the *Schizaster* morphotype (McNamara and Philip 1980) are comparable to changes which occur between species of *Pericosmus*. Changes in *Schizaster* involve increasing test size; increasing the angle of anterior slope of the test; increase in depth of paired petals and ambulacrum III; increase in depth of anterior notch; anterior lengthening of the labrum; and increase in plastron size. Similar changes have been recorded in *Micraster* (Smith 1984).

The changes also occur between species of *Pericosmus* in the Australian Tertiary. One difference between the two is with respect of the apical system: in *Pericosmus* there is an anterior movement; in *Schizaster* the movement is posterior. The posterior movement in *Schizaster* reflects increase in number of funnel-building tube feet, a facility not possessed by *Pericosmus*. Increase in petal depth in *Schizaster* and concomitant increase in declination of the aboral surface anterior to the apical system, and projection of the labrum, are believed to relate to the occupation of finer sediments, which necessitates optimisation of water flow over the test and to the adoral surface of the test (McNamara and Philip 1980).

The Australian Oligocene-Miocene species of *Pericosmus* all appear to have lived in coarse bioclastic limesands, apart from the youngest species *P. quasimodo*. This species, which has the deepest petals, most arched test, anteriorly positioned apical system and most projecting labrum, is preserved in marly horizons within the Port Campbell Limestone. The development of the morphological adaptations within the Australian Miocene species of *Pericosmus* may, perhaps, reflect adaptation to optimising water flow over the test, either due to occupation of finer sediments, or to living at increased depth in the sediment. Evidence for increased burrowing also comes from the relatively larger plastron possessed by the later species in the lineage; these species would thus bear a relatively greater number of burrowing adoral spines.

All modern described species referred to *Pericosmus* possess the ancestral morphology, suggesting that these more conservative, eurytopic species have persisted from the Eocene to the present day. The more highly vaulted stenotopic species, such as *P. celsus*, *P. torus* and *P. quasimodo*, were short-lived evolutionary experiments, which probably occupied more restricted niches and possessed particular morphological refinements which allowed their selection and genetic establishment. These refinements may have been made possible by the peramorphosis.

Living species of *Pericosmus* have been obtained from depths between 18 and 486 m, most occuring at about 200 m (Mortensen 1951). What little information is available on the sediment type occupied by these species indicates occurrence in both mud and sand. *Pericosmus porphyrocardius*, recently collected from north-western Australia (McNamara 1984), was obtained from depths between 309 and 420 m. Sediment from within the gut indicates that the species inhabited a foraminiferal-rich muddy substrate. Thus, the living species, all of which possess a basically conservative morphology, live in moderately deep water. Their morphology further suggests that they are ill-adapted to burrowing deeply in the fine substrate they inhabit.

Both the morphological characters of the Australian fossil species and the nature of the sediment in which they are preserved differ from their living and ancestral counterparts. The evolution of a number of short-ranging species during the Late Oligocene and Early Miocene in southern Australia probably reflects the attainment of a distinctive morphology, principally of vaulted test and sunken petals, which allowed occupation of an environment different from that of the ancestral species. Their occurrence in coarse-grained sediments suggests habitation in relatively shallow water in a high hydrodynamic environment.

Consequently, it may be suggested that from the stable, long-ranging, deeper water forms of *Pericosmus*, a series of short-lived species migrated into shallower water and inhabited a coarser sediment than their ancestors. The morphological characteristics developed by these Oligo-Miocene species may reflect the ability of the species to burrow effectively within these coarse sediments. The youngest species, *P. quasimodo*, evolved a morphology which allowed it not only to burrow deeper than its deep water ancestors, but also to inhabit finer sediments than its immediate ancestors which inhabited coarser sediment.

Acknowledgements

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The Edge-ground Stone Adze and Modern Counterparts in the Kimberley Region, Western Australia

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Abstract

Aborigines from the southern Kimberley, Western Australia have provided data on stone and shell adze blades found on surface artefact scatters. The methods of hafting these are described and illustrated with examples from Museum collections and the relationship between stone or shell bladed adzes and contemporary metal bladed adzes is discussed. The distribution of each type in the Kimberley Region is presented.

Introduction

Adzes are one of the basic components of the Australian Aboriginal woodworking tool kit. They consist of a straight or slightly curved wooden haft and a blade, the cutting edge of which is perpendicular to, but in the same plane as the centre line of the haft. Evidence for the distribution of flaked adze blades through time and space in Australia has been summarized by White and O'Connell (1982: 131), who conclude that these tools originate in late Pleistocene times and were widely utilized, particularly in the drier interior of the continent. Recently, we have examined a series of adzes from the Kimberley Region of Western Australia which lies north-west of the continent's arid zone (Figure 1). Here the many kinds of wooden artefacts used prior to white settlement are still manufactured with various types of adzes. This paper describes in detail one type of edge-ground stone adze, although other adze forms are mentioned and illustrated.

Chisel, Adze or Knife?

Adzes are usually held in both hands and used with short chopping blows made downwards and towards the body of the operator. These blows, relying on the momentum generated by the operator's arms and the weight of the tool for their effectiveness, pare thin shavings from the work. Chisels, another component of the Australian woodworking tool kit, are generally much lighter tools, and although they perform a similar function to adzes, they are driven through the work by a second tool. Both 'adze' and 'chisel' along with other names have been applied to the small edge-ground artefact which this paper describes (see McCarthy *et al.* 1946: 54 for references to earlier names). These names were based on the presumed function or occasionally the observed use of these implements.

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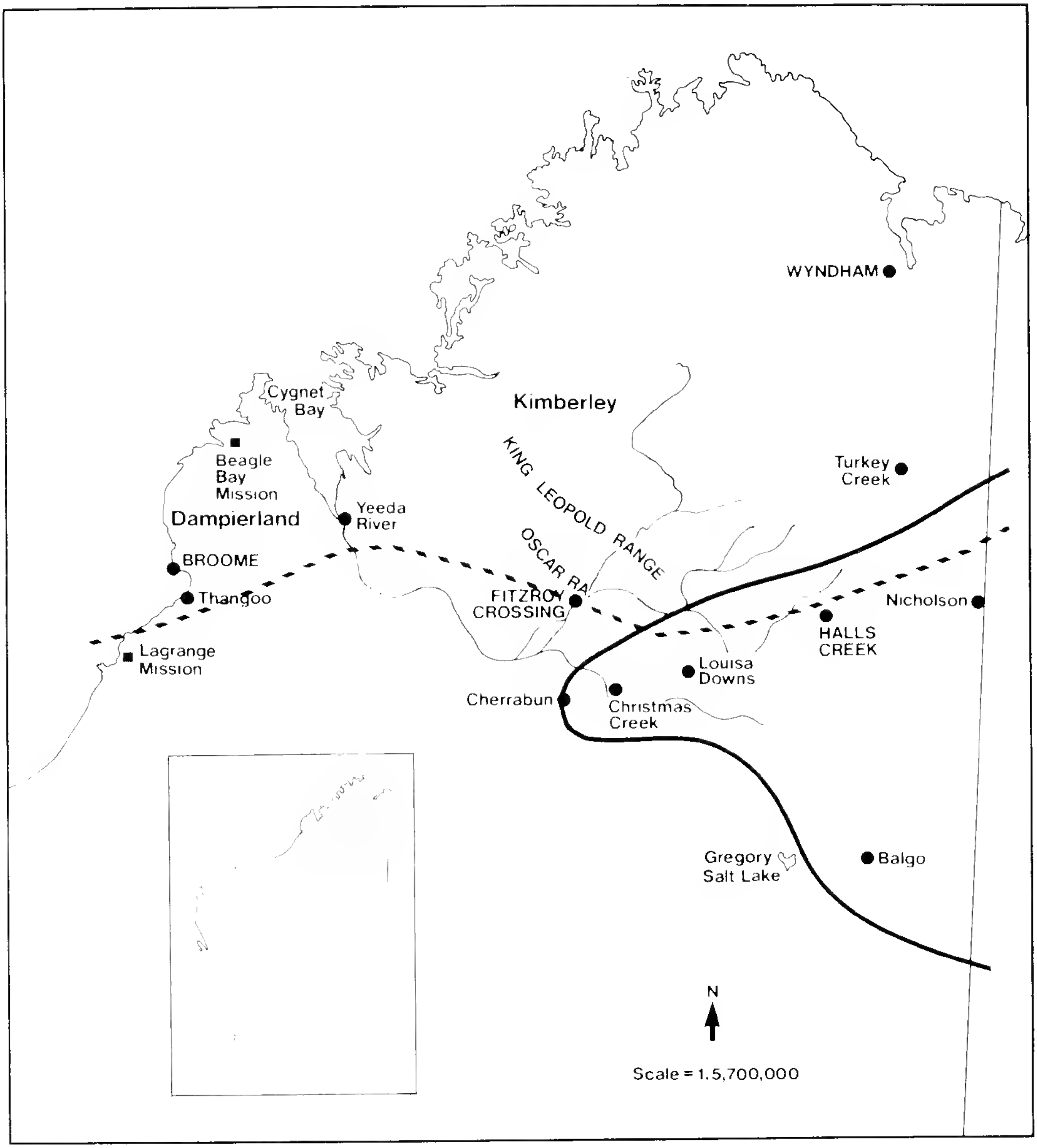

Figure 1 **Map A**

The metal adze with a tula type predecessor is found east of the solid lines however stone tula blades and slugs are more widely distributed, being found westward to the coast.

Metal adze with tula predecessor east of ——

Tula adze south of - - - -

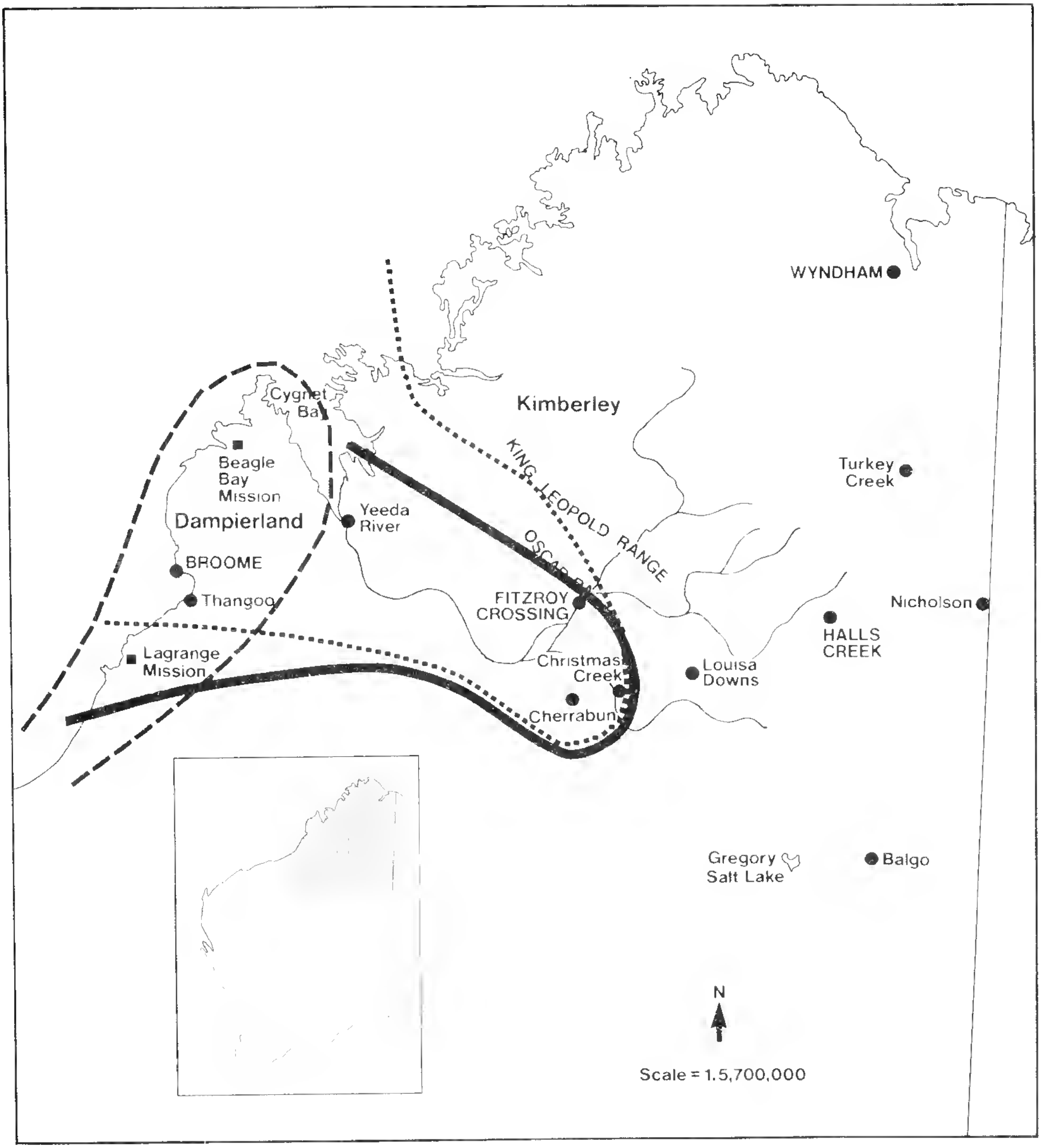

Figure 1 **Map B**

Distribution of the metal *nayi* blades follows closely that of the edge-ground stone blades, west of the dotted line.

Edge ground stone adze west of ……

Edge ground shell adze within — — — —

Metal *nayi* adze west of ▬

According to older Nyikina, Walmatjeri and Kitja informants (Kimberley tribal groups still familiar with these artefacts) the common type of edge-ground flakes were hafted and used as adzes. We have thus chosen 'Edge-ground Stone Adze' as being the most descriptive and accurate term alluding to both the form and main function of the tool type which we describe in this paper. We do not deny its incidental use as knife, chisel, scraper or the like.

Nyikina terms for components of the edge-ground stone adze are:

handle or haft – *Kangka*, of Beauhinia wood (*Lysiphyllum cunninghamii*) (*Tjikal*)
stone element – (a) *Tjirimi*
or
(b) *Tjintapal* – this term is used also for the ground shell adze
sinew – (a) *Tjiliwa* – leg sinews of kangaroo or emu
or
(b) *Nyilingka* – tail sinew of kangaroo
resin from spinifex hummock grass (*Triodia* sp.) – *Limirri*

Edge-ground Stone Adzes

Large edge-ground artefacts similar in form to Pacific Island adze blades have been reported from various parts of Australia (Davidson 1938, McCarthy 1944 and 1976). Generally, adzes from the Pacific Region have asymmetrical blades, the working edge of which is perpendicular to, but offset from the central axis of the stone blade when viewed from the side (Figure 2a). Some of these tools are probably not indigenous and it is likely that the others are merely variants of edge-ground hatchet blades. There seems to be no evidence for assuming that these objects were hafted in any other manner than is usual for Australian hatchets (Dickson 1976: 259 and 1982). Unlike the edge-ground adzes of the Pacific Region, the diminutive Australian example has its cutting edge in line with the central axis of the artefact (Figure 2b). Also, our ethnographic investigation indicates that in the Kimberley it was used in a manner similar to that described for other types of adzes seen in the desert by observers like Spencer and Gillen (1904: 634ff) or Gould 1969: 79).

Several early writers commenting on the stone artefacts of south-eastern Australia, include edge-ground adzes and chisels in a wide 'knife' category along with *Bulga* knives or skin-scapers. They describe the latter as elongated artefacts with one long straight or slightly curving edge-ground margin (e.g. McCarthy *et al.* 1946: 55; McCarthy 1976: 53) (Figure 2c). This is in contrast to the typical edge-round adze where the grinding occurs on one of the narrower margins (Mitchell 1949: 86). Some examples of Kimberley edge-ground adzes have more than 50% of their edges modified (Figure 5b), but their highly curved working edge and small size distinguishes them from *Bulga* knives, many of which were probably equipped with a simple gum grip (McCarthy *et al.* Fig. 299) and not hafted in the way described later in this paper.

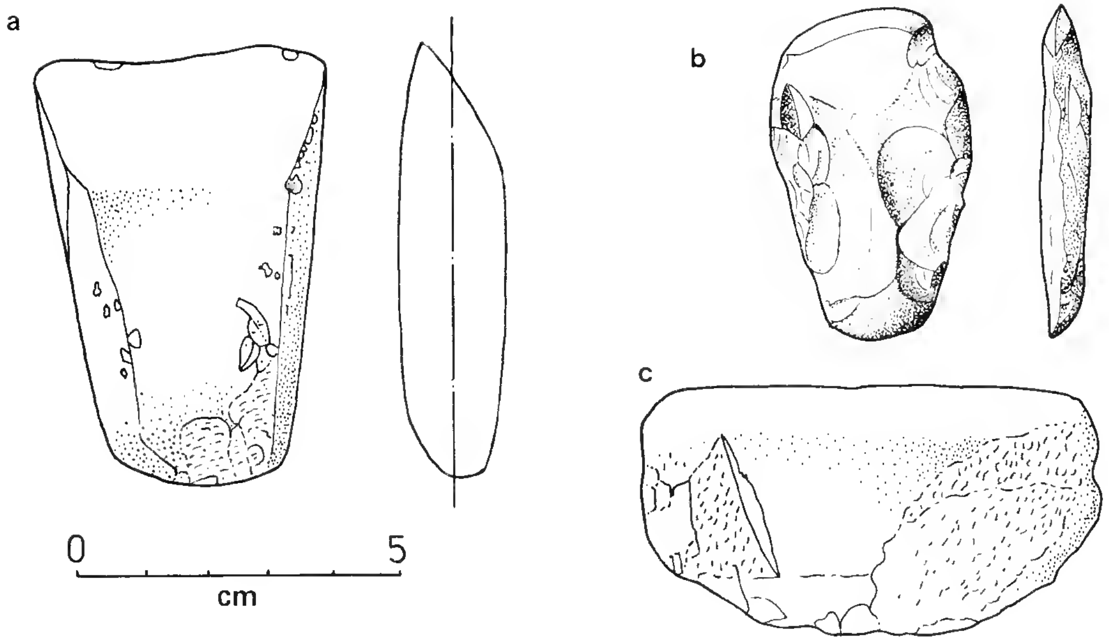

Figure 2 (a) Two views of an edge-ground stone adze blade from the Pacific showing cutting edge off-set from central axis of tool when viewed form the side. New Zealand. (WAM E.147).

(b) Two views of an Australian edge-ground stone adze blade, Christmas Creek Station. (WAM B5524/1).

(c) Skin-scaper, the ground edge on one of the long sides, and presumably used unhafted. New South Wales (re-drawn from Thorpe and McCarthy, Plate 9).

No Kimberley edge-ground adzes have been seen with battered or percussion marked edges opposite the blade, indicative of use as unhafted wedges or true driven chisels. Examples bearing evidence of this type of attrition have been collected from the Kurnell Peninsula (Dickson 1982: 78) and other areas of N.S.W. (White and O'Connell 1982: 128). Such artefacts are generally made on elongated pieces of raw material with one narrow end margin ground to produce the cutting edge. We suggest that the elongated edge-ground adze figured here (Figure 3a) was not driven through the work with blows from a hammer or maul, but was used with a two-handed grip in the manner described for adzes. In this instance we base our identification on both the lack of battering on the margin opposite to the blade and the opinion of Aboriginal informants. These men took particular note of the material from which the artefact is manufactured and the fairly acute working edge angle and suggested that the artefact was used to shape dishes and spearthrowers made from *marlay* (*Erythrina vespertilio*) a soft wood. This particular artefact, although uncommon in the Kimberley fits well within the size range of both edge-ground hatchet blades and edge-ground chisels, however the silicified schist from which the tool is made, while being strong enough to permit its use as an adze is not sufficiently robust to withstand hammer blows without shattering.

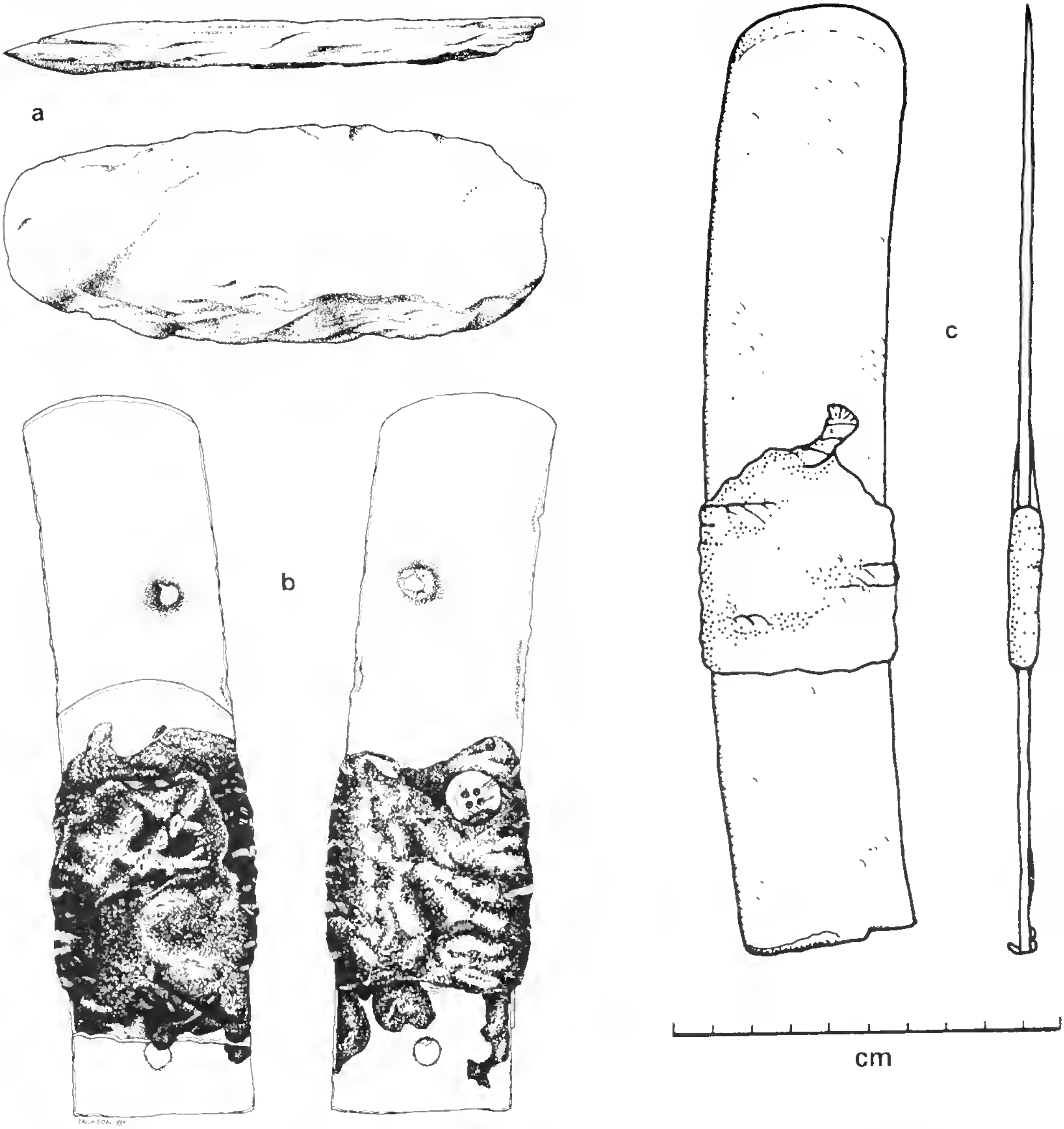

Figure 3

(a) Two views of an edge-ground stone adze made from a slab of silicified schist and used unhafted. Palm Springs, Louisa Downs Stn. (U.W.A. Anthropology Museum Coll.)

(b) Edge-ground metal adze used unhafted. Battered and folded edges on the end opposite to the sharpened blade indicate that this artefact has been used as a chisel. Ochred twine grip, Kimberley. (WAM A14233)

(c) Edge-ground metal adze made from a section of hoop iron. Spinifex resin and twine grip includes a button. Battered end again indicates use as a chisel. Kimberley. (WAM A14232)

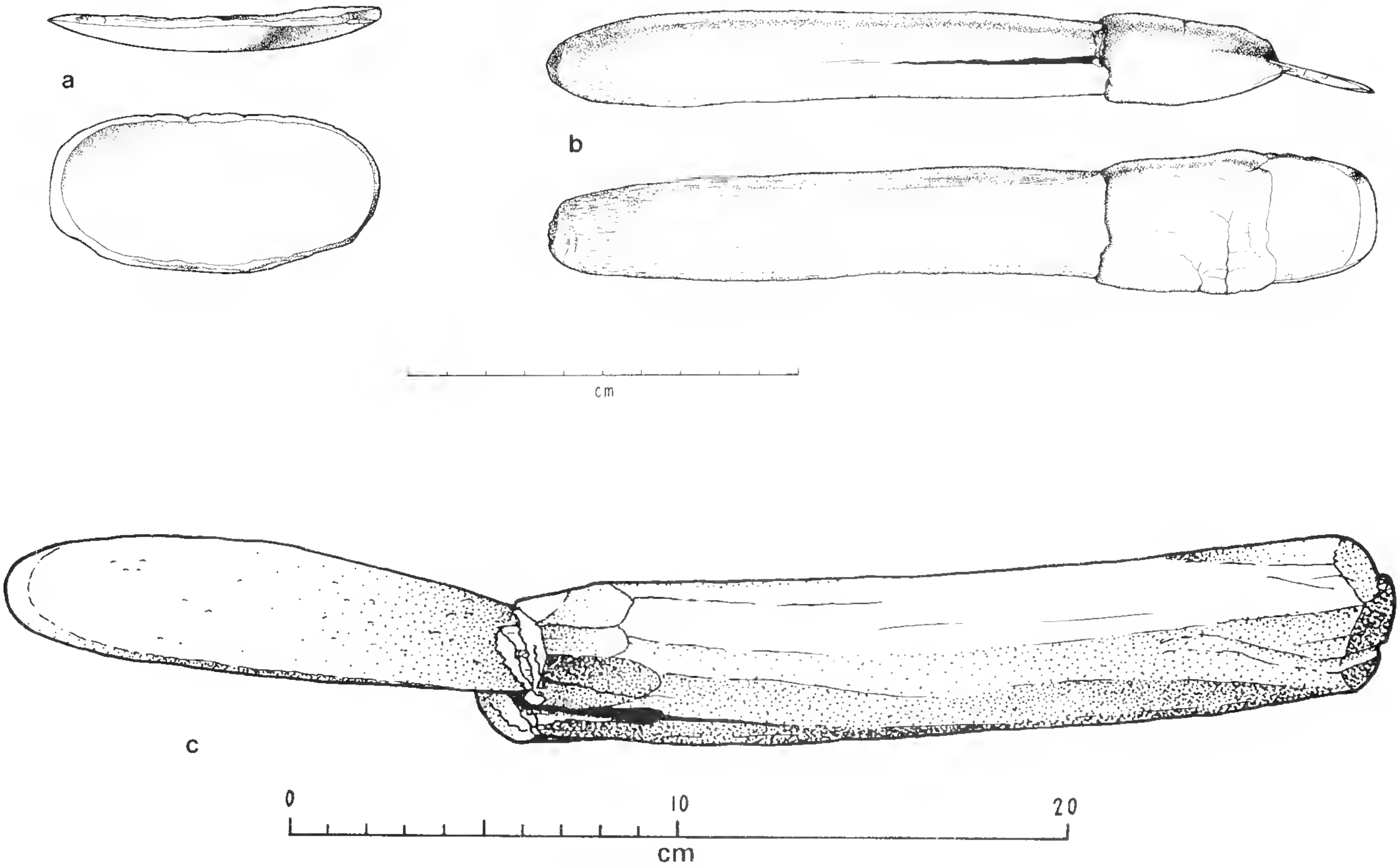

Figure 4 (a) Edge-ground shell blade. Collected from a coastal soak north of Beagle Bay Mission in 1979. (WAM A23575)

(b) Two views of a hafted shell artefact from Sunday Island (Cygnet Bay) collected 1932. Gum seal over string-bound hafting joint. (WAM 9956)

(c) Metal bladed 'nayi' adze. Found with a cache of artefacts in the Oscar Ranges in 1980. (U.W.A. Anthropology Museum Coll.)

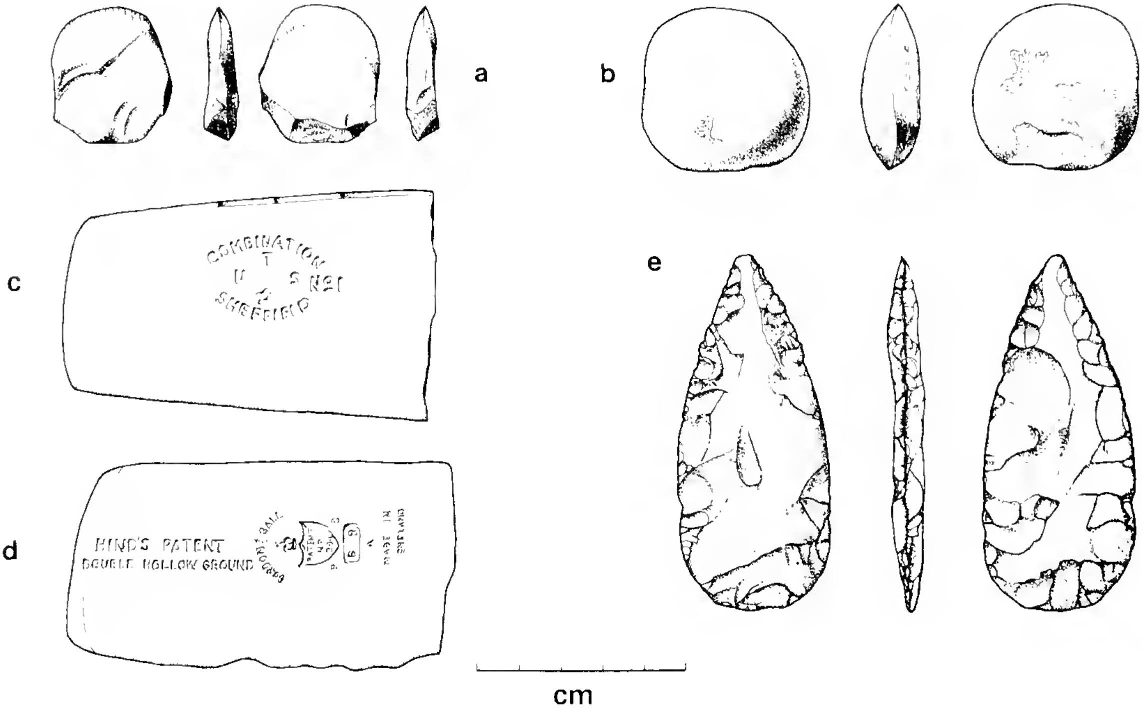

Figure 5 (a & b) Edge-ground stone adze blades. Christmas Creek Station. (WAM B5524/3 & B5524/2).

(c) Metal adze blade made from section of hand-shear blade. Traded unhafted between two men 1/6/81 south of Balgo. (U.W.A. Anthropology Museum Coll.)

(d) Similar metal shear blade trade item, Kimberley. (U.W.A. Anthropology Museum Coll.)

(e) Edge-ground flaked point, ground for use unhafted, as a tool to produce narrow grooves in wooden artefacts. Old Cherrabun Station. (WAM B4297)

Edge-ground stone adze blades vary considerably in both size and shape. Large examples may be difficult to distinguish from small edge-ground hatchet blades (e.g. McCarthy *et al.* 1946: 55). Some, in terms of their length and width fall into the acceptable range of hatchet heads. However as the adze blades are relatively thin and light in relation to their size, it seems unlikely that they were used as hatchets. future morpho-metrical studies and examination of edge wear will probably clarify the dividing line between large edge-ground adze blades and small hatchet blades.

Throughout their known geographical range edge-ground adze blades were mostly made of flakes of tough, medium grained, crystalline, indurated or volcanic rocks, lacking planes of easy fracture and similar to those from which edge-ground hatchets are manufactured (Dickson 1972). The Kimberley examples are made on a variety of materials including ultramafics, hornfels, dolerite, silicified tuffs and occasionally silicified schists. Edge-grinding may take place directly on suitable otherwise unmodified pebbles or primary flakes, or on

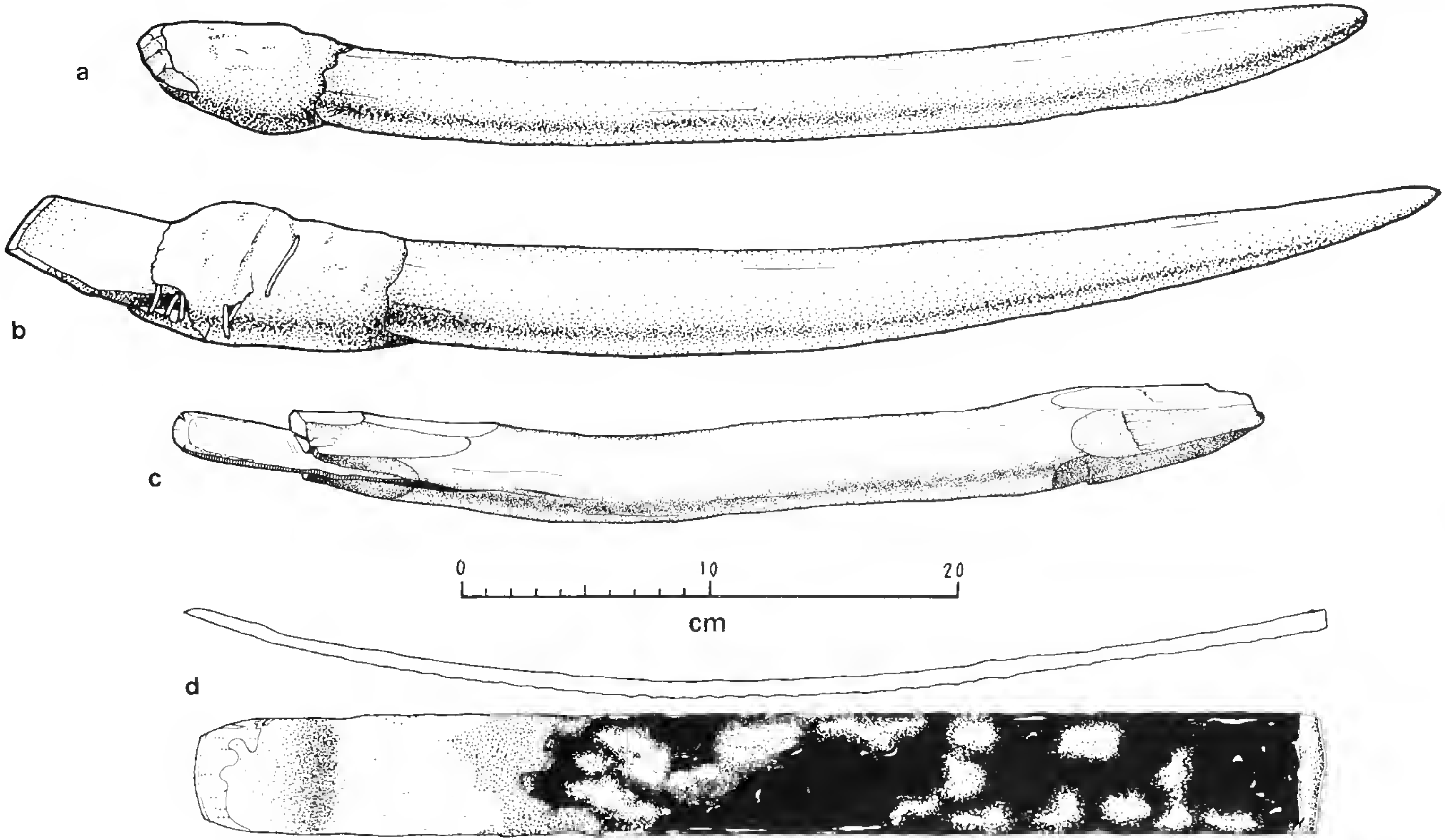

Figure 6

(a) Tula flaked stone adze blade hafted on wooden handle with Triodia sp. resin. Made by Wirili Tjabangari in 1981. Christmas Creek Station. (U.W.A. Anthropology Museum Coll.)

(b) Shear blade section hafted as an adze using copper wire and Triodia sp. resin. Made by Tjantjanu (Jimmy) Tjambitjin, Balgo. (U.W.A. Anthropology Museum Coll.)

(c) Metal bladed adze, the blade forged and ground from a section of metal file. Made by Wiminytji. Balgo, 1981. (U.W.A. Anthropology Museum Coll.)

(d) Face and side views of a section of car-spring, with one end forged and filed to conform to the blade shape of composite adzes. Made by David Downs, Fitzroy Crossing 1982. (WAM A23561)

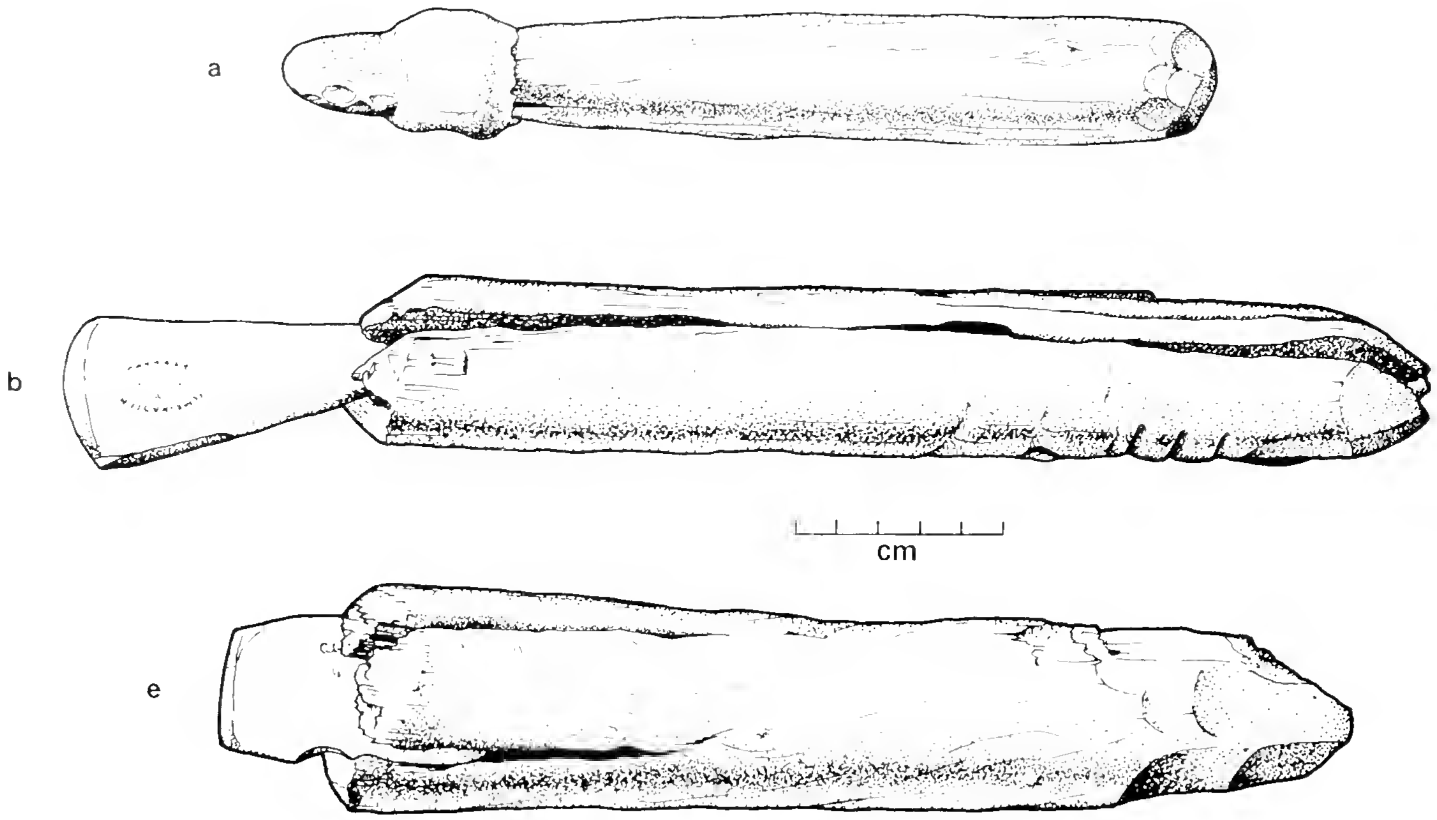

Figure 7 (a) Edge-ground stone adze, made by Paddy Roe (Nyikina speaking man) Broome in 1981. (U.W.A. Anthropology Museum Coll.)
(b) Metal bladed 'nayi' adze. Blade made from section of hand-shear blade. Wide splits in the handle have been used with a wooden fire-saw to produce fire. Collected in 1961 from Christmas Creek Station. (WAM A13810)
(c) Metal bladed 'nayi' adze collected in 1931. Blade made from section of hand-shear blade. As with example (b) the blade has been removed and re-hafted when the split widened and released its grip on the blade. Northern part of Canning Stock Route. (WAM 9741).

flakes that have been trimmed by secondary percussion flaking. Pieces which have been trimmed by pressure flaking also occur rarely. Kimberley edge-ground adze blades have insufficient mass for pecking or hammer-dressing blows to have taken effect and consequently this method of stone reduction was not used to shape these artefacts. Akerman has noted the modification of a bifacially flaked point to produce an edge-ground tool (1979: 81ff) although this seems to have been an unusual case (Figure 5e). The use of flakes from the blade of an edge-ground hatchet retaining one ground facet from that artefact has been noted. Such flakes could have broken accidentally from the edge of the hatchet blade during heavy chopping or they may result from re-trimming a previously damaged hatchet blade prior to re-grinding the edge.

Typical Kimberley examples of edge-ground adzes have one of the narrower flake margins bifacially ground to form the typical smooth, sharp and slightly curved cutting edge. As we have mentioned, the ratio of modified edge to unmodified edge varies considerably and rare disc-like examples ground on all edges do occur. Very few are ground all over.

We have not yet collected sufficient metrical data to establish a more specific formal 'type' for this artefact. However, the tools already examined fall into two groups: the more common pattern (Figures 2b and 5a, b) used for adzing, and elongated examples with narrow ground edges presumably used for engraving (Akerman and Bindon: in prep.) (Figure 5e).

Edge-ground Shell Adzes

Edge-ground segments of a robust shell were hafted for use as adzes and knives in Dampierland (Akerman 1975a: 18) (Figure 4). This is an area devoid of stone outcrops which could provide raw material for edge-ground artefacts. No archaeological excavation has taken place in this area so it is not yet possible to determine whether these multi-purpose artefacts replaced an adze with a stone blade or whether in fact their use extends far back in time. From the large number of shell blades occurring on surface artefact scatters in Dampierland we can assume that this composite tool occupied a significant place in the material culture of the tribal groups living there. However, the artefact is relatively easy to manufacture and the shell element, being less durable than stone, probably needed frequent replacement. Both these factors may explain the relatively greater numbers of shell blades as compared to stone blades seen on surface sites in their respective distribution areas.

Hafting

As we have mentioned, some of the larger examples of edge-ground adze blades (length > 6 cm) may have been used without hafting but most are too small to have been used in this way. Examples as small as 1.5 cm in width and less than 1 cm in length at right angles to the ground edge have been seen. The specimens we have examined from the Kimberley show scraper/adzing wear at right angles to the blade (Figure 5a), very different to that kind of use-wear which is roughly parallel to the sharpened edge, as is usually seen on knife flakes. This is in accord with the ethnographic data we have collected for those tools. Use-wear of the kind we have noticed may not be found on all the south-eastern Australian examples.

In the Kimberley area, edge-ground adze blades were hafted to a short (14-25 cm) stout piece of green Bauhinia wood (*Lysiphyllum cunninghamii*). This wood was chosen because it is very elastic and is said to grip the stone element without splitting back during use. A split a few centimeter long is made in the end of this haft. Both sides of the split are then pared down so that the end section of the haft is roughly oval, the split forming the long axis. The prepared stone blade was forced into the split without prior fitting of the stone or further adjustment to the haft. The joint was then bound tightly with sinew obtained from either kangaroo or emu. After drying this lashing was usually but not always covered with *Triodia* resin (Figure 7a). In an emergency, the stone could be adequately hafted by jamming it into a split stick with neither sinew or resin strengthening. The resin seal provides some support but more importantly is to protect the sinew from chafing whilst in use. Very small stone elements were hafted directly to a shaft with *Triodia* resin usually without prior splitting. This hafting method is not exclusive to edge-ground stone blades but is also the standard method of hafting flaked stone adzes. Akerman (1975a) describes a similar split stick method for hafting shell adzes.

In the south Kimberley, as elsewhere, the tula adze flake was hafted on either a special curved wooden haft, on a throwing stick, or further south in the desert on the proximal end of the spearthrower (Tindale 1965). Hafting involved embedding the trimmed adze flake in a prepared lump of *Triodia* resin moulded on to the end of the handle (Figure 6a). Although recorded from the desert margin to the south, adze hafts with a stone mounted in both ends have not been seen close to the Fitzroy River (Davidson and McCarthy 1957: 396).

In south-eastern Australia stone blades and chips were hafted to short sticks with plant exudates and bindings. Some of these are illustrated by Brough-Smyth (1978, *1*: 379 & 380 figs. 199 & 200) and Etheridge (1891: plate vi) amongst others. We illustrate in Figure 8, one of two similarly hafted stone implements collected from Kununurra in 1974 and said to be used as a knife, a chopper or chisel (C.E. Dortch, pers. comm. 1982). For these functions, the tool could be held in either one or two hands. Known as *binbalang* by the Miriwung peoples of the east Kimberley this type of artefact can duplicate some of the functions of the edge-ground stone adze from further west. An unmodified pointed cortical flake struck from a rounded river pebble forms the stone element of the *binbalang*. This is attached directly to the wooden handle with *Triodia* resin. Numerous cortical flakes which could be hafted to produce this tool can be found in surface scatters of artefacts adjacent to the Ord River. Apart from this occurrence, the distribution of these artefacts has not yet been established. Perhaps some were hafted in split sticks in the method described in this paper although the museum specimens which we have examined were hafted without the split handle.

Metal Counterparts to the Stone Adzes

Stone bladed woodworking tools have now been replaced by implements with metal blades. Near Balgo in 1982 we observed a large trimmed stone flake being used to smooth a spear shaft but this is an uncommon occurrence. Aboriginal woodworkers now utilize a suite of metal tools which include hatchets, chisels, gouges, rasps and files as well as adzes. The wooden handles of these metal bladed adzes follow closely the shape of those which had

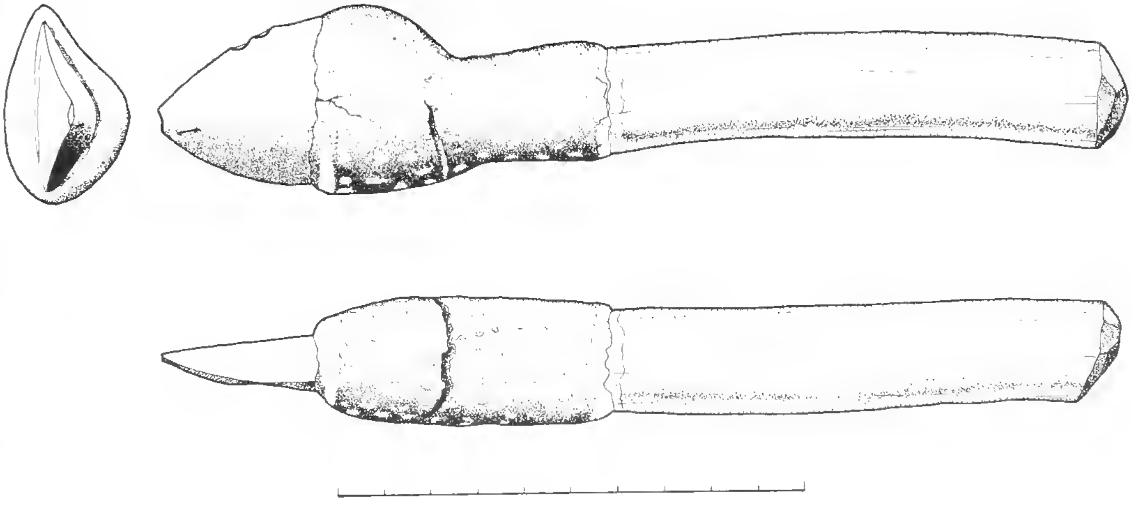

Figure 8 Three views of a hafted stone implement, known as *Binbalang*. Collected in Kununurra in 1974. (WAM A22748).

stone blades. One metal bladed adze currently used in the Kimberley follows the pattern already described for the tula where the blade is gum hafted to a wooden handle. The metal bladed example is made of a short (*c.* 8-10 cm) section of hand-shears blade (Figure 5c and d), a portion of a flat file or the metal blade of a carpenter's chisel hafted to a length of curved wood. Except for a widening of the area to which the blade will be attached, this wooden haft is identical to that which was made to accept a stone adze. The metal is attached to a suitably prepared platform on the wooden haft by binding with light wire – mostly copper wire from electrical power lines – or twine or sinew. This binding is usually reinforced with a blob of *Triodia* resin (Figure 6b). Occasionally a curved vehicle spring or a similarly shaped strip of metal about 45 cm long is made into an adze of this form by simply filing a cutting edge on one or both ends (Figure 6c). Obviously a blade of such length needs no wooden haft although sometimes a hand grip of twine and *Triodia* resin or a strip of rag is provided. Such adzes when sharpened at both ends are the only double-ended adzes found in the Fitzroy River area.

The hafted edge-ground stone adze and its shell-bladed coastal relative have been replaced by a section of shear blade or similar piece of metal of about the same thickness. In this case, a roughly oval shaped piece of metal between 12 and 15 cm long is mounted in a wooden handle about 20 cm long. Hafting is accomplished by driving the metal blade into the end of the short stout haft of *Beauhinia* wood (Figure 7b). No other lashings or adhesives are used to hold the blade in the split formed in the handle during this process, although occasionally a strip of rag may be wrapped around the junction of blade and haft to make a more comfortable grip when the tool is being used. In order to tighten the hafting, the metal blades are removed and driven into the haft again at right angles to the original split (Figure 7c and d). This adze type is known as *nayi* (Walmatjeri).

A short metal adze, related to the *nayi* adze is sometimes seen along the Fitzroy River. Sections of suitable metal about 20 cm long with one end sharpened, were used unhafted as adzes for fashioning softwood artefacts much as the stone example mentioned previously and shown in Figure 3a, was used. Occasionally the metal adzes were provided with a grip of rag or twine (Figure 3b and c) and some with battered ends, were used as true driven chisels (Figure 3b).

Sections of metal suitable for the manufacture of blades for all three adze forms are included in gift exchange between trading partners in Kimberley and adjacent communities. The most important trade routes in the south Kimberley run roughly parallel to the Fitzroy River with trade goods moving both east and west (Akerman 1979: 24). The bulk of the shear blade sections appear to originate in the west and south-west Kimberley where for several decades the pastoral industry was based on sheep.

Distribution

Concentrations of edge-ground stone adze blades are found in two parts of the continent; in New South Wales and the adjacent parts of northern Victoria and south-west Queensland, (e.g. McCarthy 1946: 53; Mitchell 1949: 84) and also in the Kimberley Region of Western Australia to which we will pay closer attention later. The edge-ground hatchet is a common artefact in both these areas, and in fact the known distributions of edge-ground hatchets and edge-ground adzes overlap, but hatchets are found much more widely.

Flaked adze forms like the tula and elouera exist alongside the edge-ground variety in both the Kimberley and south-east Australia (see for example Davidson and McCarthy 1957: 396). The adzes which occur in the south-east and centre of Australia have been adequately discussed in detail by ethnographers and archaeologists alike (e.g. Spencer and Gillen 1904; McCarthy *et al.* 1946). Forms and distribution patterns of flaked adzes in the north-west of the continent are less well known, (but see Dortch (1977) for a review of their occurrence in the east Kimberley). The distribution maps (Figure 1) show the known extent of stone and metal adzes based on either the tula or edge-ground adze predecessor. In the extreme north-west Kimberley, adzes are rarely represented in the archaeological record, and there is no reference to them in literature concerning the contact or immediate post contact material culture suite of this part of the region although other scraping tools are mentioned. Akerman has pointed out elsewhere (1979a: 245) the differences in the wooden artefact industries throughout the Kimberley which at least in part explain this omission from the stone industries.

This adzeless trend in the north continues into the present. Contemporary woodworkers tend to use steel hatchets, rasps, knives and modern chisels (not as adzes) in making shields, coolamons and spearthrowers. On the Dampierland Peninsula, woodworkers who have had nearly a century of contact with pearling and boat building industries (mainly luggers and dinghies) also tend to use a European suite of tools rather than adze forms based on traditional shell prototypes. Tulas, which are semi-discoidal flakes with varying amounts of re-trimming on the dorsal surface of the distal end and designed for hafting, are found mainly south of a line extending from Thangoo Station on the west coast to near Yeeda

Station on the Fitzroy River, to Halls Creek and thence north-easterly into the Northern Territory. Occasional specimens are seen north of this line but these are rare and there is no evidence that tula adzes occupied an important place in the artefact suite in the central and north Kimberley Plateau. Flaked non-tula adzes occur alongside the tulas. They include the burren adze (semi-discoidal flake with re-trimming on the lateral margins of the dorsal surface) and the somewhat enigmatic 'adze point' (Davidson 1935: 160-162) which lacks the tiny step flake scars on the ventral surface characteristic of other flaked adzes throughout Australia.

The general locus of the edge-ground stone adze in the Kimberley region appears to be confined to the Fitzroy River Basin and the coast to the north and south of the mouth of this river, but a few specimens occur outside this area. Our main data comes from that territory formerly held by the Nyikina speaking peoples (the middle reaches of the Fitzroy River) where the edge-ground adzes are found in conjunction with both edge-ground hatchets and tula adze flakes. On the Dampierland Peninsula, and the coast south of Broome they are found in conjunction with edge-ground baler shell adzes and knives (Akerman 1975a: 93-104 and 1975b: 16-19). Edge-ground adzes and knives are extremely rare in surface sites in the Tjaru tribal area (the open plains to the east and south-east of Halls Creek) and further eastwards. The more common artefacts on these sites include edge-ground hatchets, flaked adzes and the remnants of these, called 'slugs' which are discarded after continued resharpening renders them too small to be effective.

Conclusion

Whilst the few excavations of living sites in the west Kimberley failed to establish any temporal sequence for the full range of flaked and edge-ground adze types in the area (Blundell 1975), Dortch established the presence of adze flakes in his early Ord valley stone industry dated back to about 17,000 years ago (Dortch 1977: 109).

Examination of eroding surface sites throughout the region has revealed few edge-ground adzes occurring on sites where flaked adzes are common. Where edge-ground adzes are common, flaked adzes are rare. This suggests that the two adze types occupied a similar place in the woodworking tool kit, but over what period of time this situation existed remains to be seen. However, as the edge-ground chisels are made from rock types also used to manufacture edge-ground hatchets, the possibility exists that the smaller tools may have been made along with the latter implements. Edge-ground hatchets have been recovered from Pleistocene deposits in the Kimberley region and nearby Arnhem Land (Dortch 1977 and C. Schrire 1982).

The occurrence in adjacent areas of the edge-ground shell adze from the Dampierland Peninsula and the edge-ground stone adze of the lower Fitzroy Basin, which were both hafted in a similar fashion, suggests a close relationship between the two forms. Figure 1b shows very clearly the overlap between these two types and the metal bladed *nayi* adze. We conclude that these congruent distributions are more than coincidental and that they reflect the formal similarity between this metal bladed adze and those with edge-ground stone or shell blades.

Our observation of the present geographical occurrence of the metal bladed adze which replaced the stick hafted tula adze, indicates that the distribution has narrowed from that of its stone bladed counterpart. This is partly due to the centralisation of population, initially to stations and later to larger settlements, and partly to the heavy influence of European woodworking tools and skills. We believe that the distribution pattern that emerges demonstrates a conservatism in material culture which allowed the adoption and continuation of two distinct adze forms in the southern Kimberley.

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Bionomics of the Bee *Stenotritus greavesi* and Ethological Characteristics of Stenotritidae (Hymenoptera)

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Abstract

A nest aggregation of *S. greavesi* in south-western Australia is described. Females nested individually in bare ground. Nests were very shallow but essentially like those described for other stenotritids and particularly *Ctenocolletes ordensis*. Additional data on adult behaviour, flower preferences, phenology and parasitoids (Meloidae and Mutillidae) are included. Dormant post-defaecating larvae had unusually tough integuments that were coated with an apparently secreted film. Known habits of Stenotritidae are discussed and the ancestral and derived ethological characteristics of the family postulated.

Introduction

The genera *Stenotritus* Smith and *Ctenocolletes* Cockerell comprise the endemic Australian family Stenotritidae. Details of the bionomics of stenotritids have become available only comparatively recently (Houston 1975, 1984). Nests have been described only for *S. pubescens* (Smith) and *C. ordensis* Michener. These species are essentially solitary and ground-nesting. While their nests are basically similar, some differences were noted. The cell closures of *ordensis* were more elaborate and the question arose (Houston 1984) whether some details of construction may have been overlooked in *pubescens* nests. If not, were the differences of specific or generic significance?

An opportunity to investigate the habits of stenotritids further arose with discovery of an active nest aggregation of another *Stenotritus* species at Boorabbin Rock, about 93 km east of Southern Cross, Western Australia, on 8 October 1981. On that occasion and the following day we excavated several nests and observed adult activity at and near the nest site. One of us (TFH) revisited the site and made further excavations on 21 January 1982 and obtained additional data from specimens in the Western Australian Museum, Perth (WAM).

In this paper we present our observations and compare the nests and habits of *S. greavesi* with those of previously studied stenotritid species.

The genus *Stenotritus* is much in need of revision and includes several undescribed species. Identification of our Boorabbin Rock species followed a check of all species descriptions and a comparison of specimens with the holotype of *S. greavesi* (Rayment, 1930). Adult and immature specimens taken during the course of our study are lodged in WAM. Additional adults are deposited in the Bohart Museum of Entomology, University of California, Davis.

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Figure 1 Nest site of *Stenotritus greavesi* at Boorabbin Rock, W.A. Burrows occurred in foreground within 1 m of the rock wall.

Observations

Nest Site

Female bees were found entering and leaving burrows in an area of bare level ground at the edge of the Boorabbin Rock granite exposure (Figure 1). The area was margined on the rock side by a stone and concrete retaining wall forming part of a rainwater catchment system and on the other side by 2-3 m tall shrubs (*Thryptomene tuberculata*). Burrows were confined to a 3.5 m long, 1 m wide strip near the wall and about 35 entrances were randomly scattered there. The sandy loam soil overlay a granite rock basement to a depth of about 43 cm and was riddled with roots and termite galleries. The top 13 cm or so was dry and powdery while the deeper soil was moist and firmer.

Nest Architecture

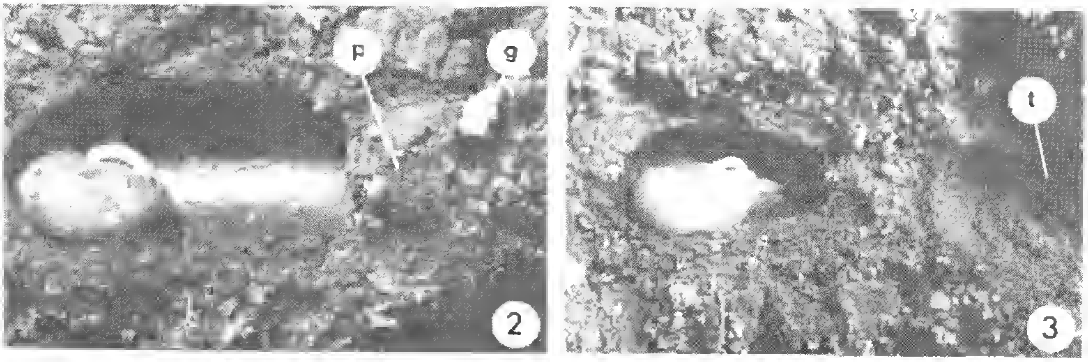
Burrow entrances were simple irregular holes with neither turrets nor conspicuous tumuli (a few had a little loose soil cast to one side). Some occurred in the open and others beneath the edges of stones and exposed roots. Shafts descended at angles of 45° or less to the horizontal (Figures 4, 5) and bent laterally irregularly, some turning through more than 90°.

They were circular in cross section, 9 mm in diameter and extended an average of 35 cm (but not exceeding a depth of 16 cm). Their walls were mostly unworked but, in a few nests, portions had clearly been cemented-in where the shaft passed through soil that was very soft or honeycombed with termite galleries.

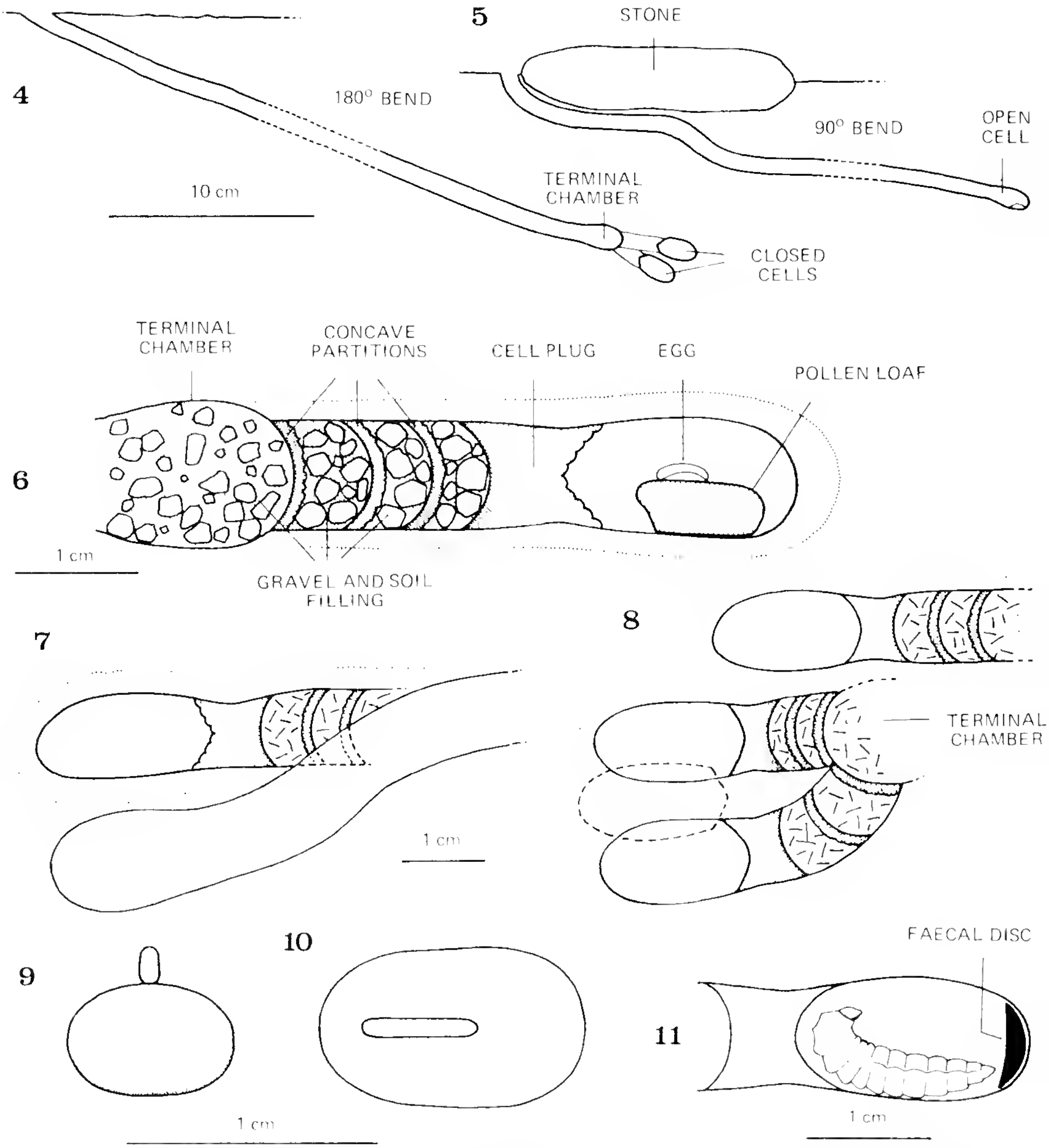
Brood cells occurred at and near the ends of shafts (Figures 4, 5, 7, 8) 9-16 cm below the surface and chiefly above the moist soil zone. Five nests still under construction in October had one or two cells. Completed nests (judging from a few that were inhabited and several that were vacated) may have from 1-4 cells but most had two. In all cases where there was more than one per nest, cells were side by side or one above the other, never end to end. Long axes of cells were mostly horizontal or nearly so; only one was steeply dipped.

The earthen walls of cells were continuous with those of their access burrows (Figure 6) and much firmer than the surrounding soil. Consequently, cells were easily detectable during excavation and could be removed intact. Internally, they were rather ovoid (slightly flatter on their lower side and truncated at the plug end) (Figures 2, 3, 6), 9 mm in diameter and about 18 mm long. Their inner walls were extremely smooth, chocolate-brown, shiny and water-proofed as far as their necks. The water-proofing material was generally inseparable from the earthen wall but in one cell a small portion had lifted and could be peeled away like a stiff plastic film. When a portion of a cell was soaked overnight in water and detergent, a delicate transparent brownish membrane separated within it. Under the microscope the membrane appeared amorphous (having no fibrous inclusions as do colletid membranes; Batra 1972). It was insoluble in xylene and turpentine and did not melt when heated. Probably, it was a laminester film (*sensu* Hefetz, *et al.* 1979).

The inner walls of cells are evidently built in. In one open active nest examined, the shaft terminated in a rough-walled ovoid chamber, 12 mm in diameter, adjacent to a freshly completed cell (Figure 7). The chamber was probably a roughed-out cell and, given a 1.5 mm thick coating, its diameter would reduce to 9 mm (the observed diameter of completed cells). However, since the solidified walls of cells are mostly about 3 mm thick, it seems likely that the bees also impregnate the soil with some cementing liquid.



Figures 2-3 Newly completed brood cells opened from side showing pollen loaves with eggs, cell plug (p), gravel filling (g) and terminal chamber (t).



Figures 4-11 Nests and provisions of *Stenotritus greavesi* (dotted lines define cemented earthen walls of cells and access burrows). (4 and 5) profiles of incomplete nests (drawn as if in one vertical plane but burrows bent laterally as indicated by broken lines); (6) sagittal section of freshly completed cell, access burrow and terminal chamber of shaft; (7) shaft ending in simple chamber (roughed-out cell?) adjacent to newly completed cell; (8) cluster of four cells from nest of previous season (contained pupae) (to same scale as 7; detail to right side lost in excavation). (9 & 10) end and top views of pollen loaf bearing egg; (11) sagittal section of cell with post-defaecating larva and faecal disc (solid black)

Cells were closed by earthen plugs and access burrows filled with soil. A cursory inspection may reveal no more than a solid earth barricade in the access burrow but the closures were quite elaborate (Figures 2, 6). The plug in the cell neck consisted of compacted fine soil and showed a spiral pattern on its concave inner (cell-side) surface. Its outer surface was cemented, concave and very smooth like the inner end of a cell (except that it was not varnished, shiny and waterproof). Following this in the access burrow were usually two further 'false cell-base' septa separated by 1-4 mm. The chambers so formed were packed with gravel and soil, incorporating particles up to 4 mm in maximum width.

In some nests, an ovoid chamber 12 mm in diameter was found where the access burrows of two or more cells joined the shaft (Figures 3, 4, 8). Its end wall was smoothly concave and cemented. In closed nests the chamber was filled with gravel and soil.

Provisions

Several freshly provisioned and closed cells were obtained in October. The provisions consisted of a solid moist pollen loaf of characteristic shape (Figures 2, 3, 6, 9, 10) but no free liquid. The loaves were dull yellow, uniformly moist throughout, uncoated and moderately variable in size (dimensions in mm of four samples were length 8.2-11.0, width 5.6-6.7, height 4.5-4.9). One open cell being provisioned contained an amorphous heap of moist pollen indicating that formation of the loaf occurs at the end of provisioning.

The composition of some of the pollen loaves is discussed below under Food Plants and Foraging.

Immatures

Eggs were deposited atop the pollen loaves, each resting on its ends and situated nearer the cell mouth end (Figures 2, 3, 6, 9, 10).

No larvae were encountered in October but, in January, 18 mature post-defaecating larvae were obtained (Figure 12). They were not enclosed in cocoons but rested with their heads towards the cell plugs and were in dormant condition. They were unusual for Hymenoptera larvae in having stiff creamy brown integuments. This condition is attributable (at least in part) to a thin transparent amorphous film overlying the body integument but not the head. The film was not noticed on live larvae but was detected in spirit-preserved specimens in which it had separated from the underlying integument. It appears to be a secreted coating.

In the base of cells with dormant larvae were hard blackish brown faecal discs moulded to the shape of the walls (Figure 11). The plugs of such cells, too, had been altered, their inner surfaces being smoothed and concave (Figures 8, 11) with no trace of a spiral pattern and some of their soil being smeared over adjacent portions of the cell wall. Presumably mature larvae writhe about, compressing loose faeces into solid discs and, at the same time, abraiding their cell plugs.

Several larvae were kept at room temperature in vials but only one developed, pupating on 25 September and becoming adult on 14 November, 1982. The remaining larvae gradually shrivelled despite being placed on moist tissues during September.

Figure 12 Dormant post-defaecating larvae of *S. greavesi* and coarctate larva of meloid beetle (bottom right) taken from brood cells in January. Scale line = 1 cm.

Associated Organisms

Two kinds of parasitoids were obtained from cells. In October, a triungulin (Coleoptera: Meloidae) was found crawling on the pollen loaf of a newly completed cell and a coarctate larva of the same family was taken from a cell in January (Figure 12). The latter specimen was kept at room temperature but had not developed at the time of writing (June 1983). In October, several cells containing cocoons were encountered. A few cocoons were old and vacated but three were occupied and yielded adult Mutillidae (Hymenoptera) of both sexes in late November 1981. These specimens were identified as '*Ephutomorpha*' sp. near *morosa* (Westwood) (D.J. Brothers pers. comm.). In the base of each cell outside the cocoons were the usual faecal discs so the mutillids must have developed on post-defaecating host larvae. The cocoons consisted of an outer delicate papery membrane applied to the cell walls (this was very incomplete in some cases) and a thick inner capsule spun of dull golden silk and suspended in a lattice-work of the same fibres.

No adult parasitoids were observed active at the nest site on either visit and no signs of gasteruptiid wasp infestation (as observed in nests of other stenotritids) were noted.

Adult Behaviour

Adults were active at the nest site only on the October visit. On that occasion, adults were still emerging from brood cells of the previous generation as pharate and newly emerged individuals were present in some of them. Several females were observed hovering over the nest area as if searching for suitable places to burrow. Others were returning laden with pollen: they hovered in as they orientated towards their burrows and, when about 15 cm above them, plummetted swiftly into the entrances. Departing females left their burrows rapidly and without warning. Some burrow entrances were blocked by their occupants pushing up soil from below but mostly they were left open. Entrances of most active burrows were blocked overnight after females made their last return. Of 16 plugged entrances, 11 were opened between 9:15 and 11:21 on 9 October by females pushing the loose soil inward. Females often positioned themselves just inside the entrance moving back into the tunnel if disturbed by movements of the observer.

A few males were observed in nest burrows. One male appeared at 9:30 on 9 October just within and facing out of an unplugged burrow where it had spent the night. A small net was placed over the entrance and the male was captured as it exited at 11:43. During the middle portion of the day, many more hovered persistently along the bank of *Thryptomene* shrubs facing the nest area. Each male hovered almost stationary with its fore and mid legs tucked beneath its body and its hind legs projecting slightly outward and rearward. Males periodically darted off in pursuit of a neighbouring male or some passing insect or occasionally patrolled a section of shrubbery usually returning to its original hovering post as if defending a territory. Similar behaviour in solitary males was observed (by TFH) on 27 October 1978, 3.5 km south of Yellowdine, W.A. One male hovered near a flowerless shrub and two others in spaces between flowering bushes of *Verticordia chrysantha.* Although males at Boorabbin Rock were occasionally observed to swoop down after females arriving at their nests, no matings were observed.

First observations of activity at and near the nest site were made on 8 October at about 13:30 when males were patrolling and females were entering and leaving nests. By 14:40 only one male was seen flying and some marked nests which were earlier open and active were plugged with soil just within the entrances. From 15:00 to 17:00, while we excavated nests, we saw no males in flight and three females that returned without pollen and were apparently confused by disturbance of landmarks, were the only ones active.

Adults were not active at the site when we arrived on 9 October at 8:15 (temperature 14°C). The first female appeared just inside the entrance after unplugging her burrow at 9:15 (16°C). The first female leaving a burrow did so by 10:00 (19°C) by which time there had appeared heads of three females at the entrances of burrows blocked overnight and two more females and the male noted above in unplugged burrows. The first female with a pollen load returned at 11:04. Males were active in their territories by 10:48. Although difficult to observe due to their rapidity of egress and entry, durations of trips from and to nests and times in nests between trips were measured for several females between 10:00 to 11:57. Females returning with pollen averaged 22.7 (± SE 5.85) minutes (N = 7) for foraging trips and 6.5 (± SE 2.12) minutes (N = 2) in the nest between trips. Females returning without pollen loads averaged 25.7 (± SE 18.77) minutes (N = 3) away from the nest and 11.7 (± SE 11.24) minutes (N = 3) between trips. (The high variance for females without pollen loads is not just a function of small sample size but reflects the greater range in times for activities in contrast to the rather regular timing of pollen foraging. It may be that females without pollen loads were each engaged in quite different activities such as nectar foraging or orientation.) One female unplugged her burrow at 10:07, left at 10:35, returned unobserved and replugged her burrow at 11:19 and reopened it at 11:57 when observations ceased. Of 16 burrows plugged when observations began, only 11 were opened and active during the morning. In addition, 4 of 19 open burrows were active during this time. Three of these had females, all of which foraged for pollen, and one contained a male which had spent the night.

Food Plants and Foraging

The recorded food plants of the species based on WAM specimens are listed in Table 1. Also shown in the table are the pollens identified in scopal loads on nine females. Additional data on pollen sources were obtained by microscopic examination of samples from five fresh pollen loaves. Four of the latter consisted entirely of myrtaceous pollen (matching that of *Melaleuca scabra*) and one was composed of 75% of this same pollen mixed with an unidentified myrtaceous species.

The data suggest that *Melaleuca scabra* is the favoured pollen source with *Cheiranthera filifolia* and *Hakea* (or perhaps *Grevillea*) providing lesser amounts. *Verticordia chrysantha* evidently serves as a nectar source. Females must at times visit more than one plant species during a single foraging trip as evidenced by the mixed loads of four individuals. However, in only one case were the two pollens sufficiently well represented to suggest active collection of both had occurred. In the others, the additional pollens may represent contaminants from grooming following nectar visits.

Females worked feverishly while collecting pollen and scurried through the dense stamens of *Melaleuca scabra* flower heads. Flowers of *Cheiranthera filifolia* have large, yellow, apically porose anthers and the female observed working this species emitted readily audible sounds as she clutched the anthers and vibrated her thorax in the manner well known for bees (Buchmann 1983). Pollen was carried on the hind tibiae and basitarsi in large amounts that were moistened towards the end of foraging trips.

Table 1 Flowers visited and pollens carried by adults of *Stenotritus greavesi*. Relative amounts of pollen (as % total volume) were estimated visually from microscope slide preparations. M = pollen matches that of flower species visited; U = unidentified species.

Flowers visited	Numbers of bees		Pollens carried on scopae	No. of females
Baeckea ?leptospermoides		1♀		
Cheiranthera filifolia		1♀	*Cheiranthera* (M, 75%), *?Hakea* + Myrtaceae (equal)	1
Melaleuca scabra		11♀	Myrtaceae (M, 100%)	5
			Myrtaceae (M, 98%) + *?Hakea*	1
			Cheiranthera (95%), Myrtaceae (M) + U_1 + U_2 (equal)	2
Verticordia chrysantha	1♂	3♀		

Phenology

Collection dates for 22 females in WAM range from 4 October to 8 December. However, most of these females and all ten males were collected in October. A further six females collected at New Norcia on 1 January may belong to *S. greavesi* but differ from the bulk of specimens in some details of pubescence. On 8-9 October 1981, the Boorabbin colony was in the early throes of nesting. The following January, no adults were present and larvae lay dormant in their cells. These data strongly suggest that *S. greavesi* is a univoltine vernal species.

Discussion

In terms of infrageneric relationships, *Stenotritus greavesi* and *S. pubescens* are distantly related and representative of two species groups. Their phylogenetic separation is reflected by differences in their biologies and nest architecture (although some apparent differences may not be real as will be discussed below). Characteristics of *greavesi* that differ from those of *pubescens* (given in parentheses) are as follows: nests shallow, not deeper than 16 cm (up to 32 cm deep); shafts oblique (more or less vertical) and simple (with blind diverticulae); cells constructed in dry loose soil (cells constructed in compact moist soil); all cells on separate access burrows (some cells recorded as being in linear series but this is now in doubt – see below); cell closure incorporating 'false cell-base' septa and gravel-filled chambers (cell closure and access burrow barricade recorded as solid fill but this, too, is in doubt – see below); closed nests with ovoid chamber at junction of shaft and access burrows incorporating 'false cell-base' (not observed); moulded pollen loaf bilaterally symmetrical with dissimilar ends (more or less radially symmetrical about long axis with similar ends); no free liquid in cells (clear liquid around base of pollen loaf); larvae coated with secreted film (absent); larval faeces compacted into solid disc in end of cell (deposited as separate streaks on ceiling of cell); univoltine and vernal (apparently bivoltine, summer flight season).

We alluded above to some possibly erroneous observations recorded for *pubescens*. 'False cell-bases' were not recorded in nests of that species (Houston 1975) but (as they are very inconspicuous amongst the compacted soil-filling of *greavesi* burrows) they could easily have escaped attention. It is quite possible that had a false cell-base been observed in an access burrow of *pubescens* it might have been identified as the base of one cell in series with another. Hence, the report of linear cell pairs is brought into question. This matter can only be settled with further, more critical examination of *S. pubescens* nests.

In terms of ethology and particularly nest architecture and provisions, *S. greavesi* seems to resemble *Ctenocolletes ordensis* more than *S. pubescens*. The most notable differences are that *S. greavesi* has shallower nests lacking entrance pits and gravel coats on cell walls, constructs more false cell-bases in its cell closures, constructs a chamber with false-cell base in the shaft of advanced nests, moulds narrower pollen loaves and its final instar larvae construct solid faecal discs and are coated with an apparently secreted film.

Each species probably has its own derived characteristics but features shared by *Stenotritus* and *Ctenocolletes* species may be deemed to be ancestral for the family Stenotritidae. Such are the following: essentially solitary habits although nests are aggregated and males form sleeping clusters; nests in ground; entrances without turrets or conspicuous tumuli; shafts simple, occasionally with partial built-in walls; cells few per nest, each on its own access burrow, more or less horizontal, with built-in earthen walls continuous with those of access burrows, varnished internally with thin, waterproof (possibly laminester) membrane which is not readily separable from earthen wall; cell closure consisting of spiral earthen plug, smoothed, concave and cemented externally, and followed in access burrow by one or more gravel-filled chambers closed by false cell-base septa; provisions consisting of firm, uniformly moist, uncoated, moulded, bilaterally symmetrical pollen loaf with a projection at cell plug end; egg with both ends placed on cell plug end of pollen loaf; larval faeces deposited as streaks on cell wall; no larval cocoon; univoltine, vernal, with dormancy occurring in post-defaecating larvae; pollen sources limited to few plant genera but more than one family; pollen and nectar sources often separate; mixed pollen loads sometimes collected; pollen carried on hairs of hind tibiae and basitarsi and forming large firm moist masses towards end of foraging trips; females work feverishly while pollen-collecting and are capable of employing buzzing technique to extract pollen from anthers with apical pores; males frequently establish and hover in territories; males roost singly or gregariously on foliage.

The separation of Stenotritidae from Colletidae (McGinley 1980) is supported by what is now known of stenotritid habits which seem more to resemble those of Andrenidae. Stenotritid nests differ most notably from those of colletids in the absence of cellophane-like membranes, in having built-in walls in access burrows and cells, false cell-bases and concentrations of gravel in cell closures, and bilaterally symmetrical pollen loaves (all but the first of these features also distinguish stenotritid from andrenid nests and can be regarded as stenotritid synapomorphies). Although Andrenidae are not known to construct concave partitions, some species (Panurginae) form cell plugs with smooth concave external surfaces (see Houston 1984: 167).

The films covering post-defaecating larvae of *S. greavesi* are unusual and may be an adaptation to aid water conservation necessitated by the very shallow, dry-soil nests. Rozen (1967: 14) records that the integument of post-defaecating larvae of panurgine bees (Andrenidae) is tough and apparently coated with a waterproof secretion. Probably the films arose independently in the two families.

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Description of a New Monacanthid Fish of the Genus *Thamnaconus* from Fiji

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Abstract

A new species of monacanthid fish, *Thamnaconus fijiensis*, is described from Fiji. It is distinguished from other members of the genus by the 4-5 lines of spots along the side of the body. *T. fajardoi* Smith from off the east coast of Africa appears to be its closest relative, differing only in the more closely spaced body spotting and noticeably larger scales.

Introduction

The monacanthid fish genus *Thamnaconus* Smith is the richest genus in the family with a known total of 15 species (Hutchins, in preparation). However, most of its members are poorly known mainly because of their generally deep water habitats (to 360 m). Also the species have been placed in a variety of genera including *Cantherhines* Swainson, *Navodon* Whitley (a junior synonym of *Meuschenia* Whitley, see Hutchins 1977) and *Pseudomonacanthus* Bleeker, thus their relationships have remained obscure. Smith (1949) described *Thamnaconus* for *Cantherhines arenaceus* Barnard, a South African species. At the same time he included another South African species, *T. modestoides* (Barnard), and subsequently (1953) described *T. fajardoi* from the Mosambique Channel. Recently the generic name has been applied to other species from Australia, Japan and Hawaii (see Hutchins 1977; Zama and Yasuda 1979; Hutchins and Randall 1982; Springer 1982). The purpose of this paper is to describe a new species of *Thamnaconus* from Fiji and to compare it with the closely related *T. fajardoi*.

Measurements and counts follow Hutchins (1977). The holotype is housed at the University of the South Pacific, Fiji (USP).

Systematics

Thamnaconus fijiensis sp. nov.

Figures 1, 2 and 3

Holotype

USP 4541, 137 mm SL, collected by fish trap outside Suva Barrier Reef, Fiji, 183 m deep, 16 January 1980.

Diagnosis

This species is placed in the genus *Thamnaconus* on the basis of its elevated anterior dorsal and anal fin rays, the laterally-directed barbs in the posterolateral series on the first dorsal

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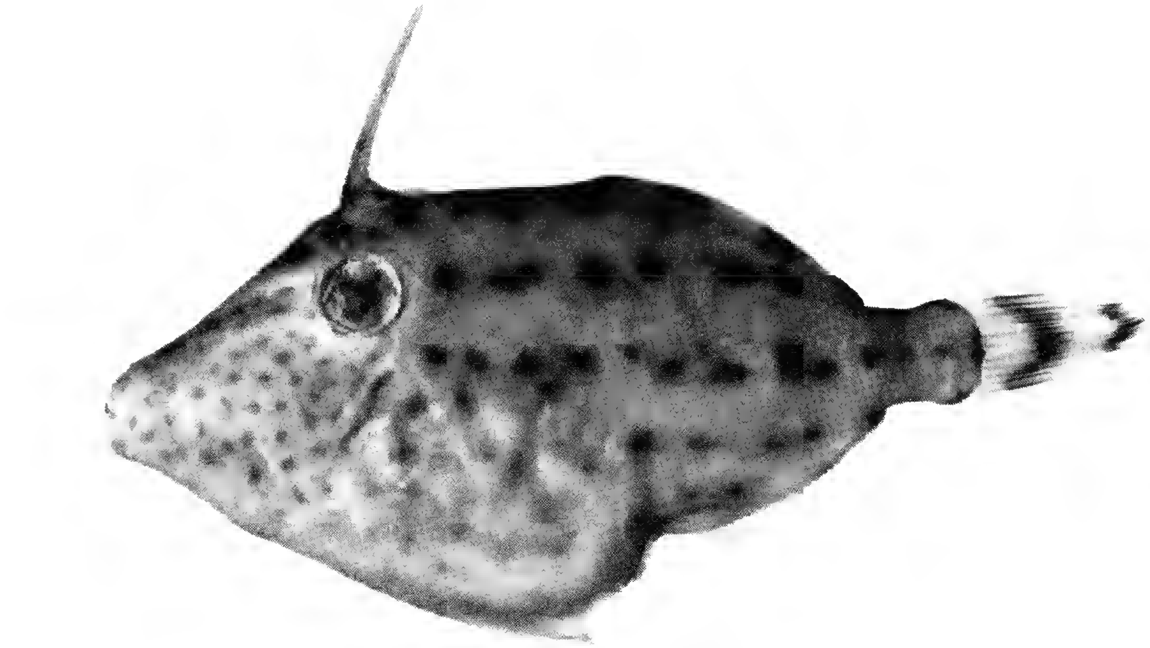

Figure 1 *Thamnaconus fijiensis* sp. nov., holotype, 137 mm SL.

spine, the two pairs of encasing scales fused immovably to the posterior end of the pelvis, and the 19 vertebrae. It is distinguished from other species of *Thamnaconus* by the 4-5 lines of dark spots along the side of the body, the others being either non-spotted, covered with very small dark spots, or possessing larger spots which do not form 4-5 lines along the side. *T. fajardoi* is most closely related to *T. fijiensis*, but its body is almost entirely covered with moderate-sized dark spots (in small specimens the upper 1-2 series tend to form lines) and noticeably larger scales.

Description

Dorsal fin rays 33; anal fin rays 32; pectoral fin rays 13-14; caudal fin rays 12; vertebrae 7 + 12 = 19.

Body compressed and moderately deep, width 2.4 in head length and depth 2.3 in SL; head length 2.9 in SL; profile of snout concave (lateral view), length 3.5 in SL; eye diameter 3.4 in head length, 1.1 in interorbital width; gill slit length 3.2 in head length, centered below and slightly anterior to centre of eye; pelvis capable of moving vertically through an arc of about 15°, producing a moderate-sized ventral flap.

Mouth small, terminal, lips not fleshy; dentition normal, consisting of 3 outer and 2 inner teeth on each side of upper jaw, extremities of inner teeth projecting between outer teeth; 3 teeth on each side of lower jaw, posteriormost small; extremities of all external teeth except posteriormost in each jaw pointed.

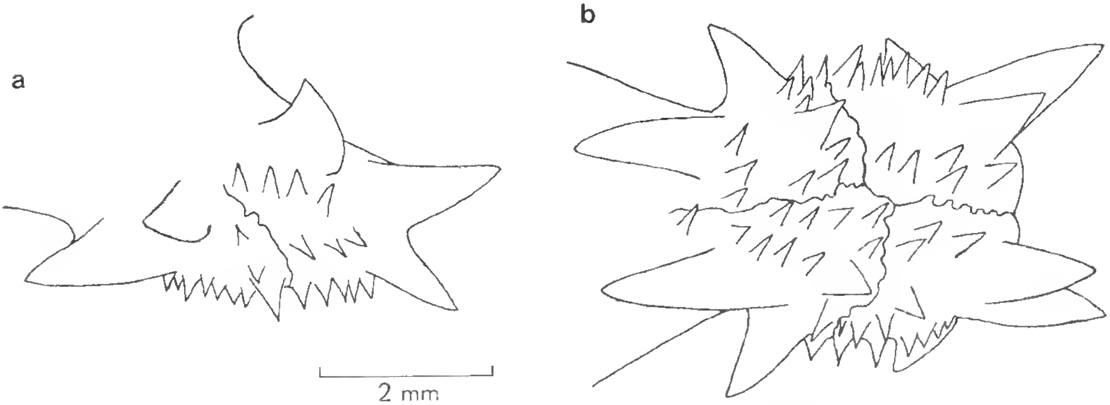

Figure 2 Lateral (a) and ventral views (b) of the pelvic fin rudiment of *Thamnaconus fijiensis* sp. nov., holotype.

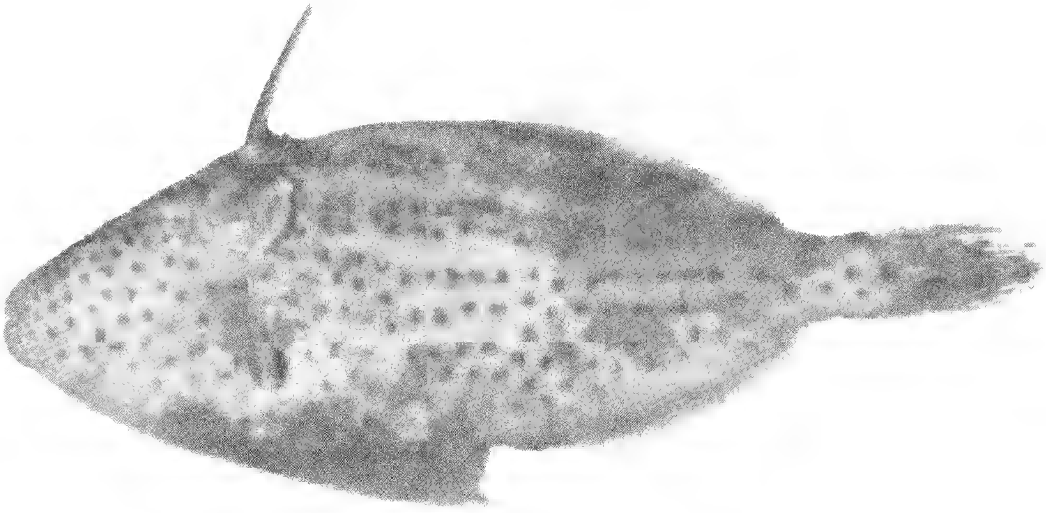

Figure 3 *Thamnaconus fajardoi*, MNHN 1983-315, 179 mm SL.

First dorsal spine strong and moderate in length (1.3 in head length), originating over anterior third of eye, received partly into shallow groove in back when depressed; dorsal spine armed with 4 series of downward-directed barbs, anterior face with 2 adjoining rows (some anterior barbs on lower half of spine also have short upward-directed projections), each posterolateral series directed laterally and numbering about 21; second dorsal spine small, hidden in skin at rear base of first spine; soft dorsal and anal fin rays moderately elevated anteriorly, longest (9th) dorsal ray 2.6 in head length, slightly longer than longest anal ray; length of soft dorsal fin base 2.9, length of anal fin base 3.4, both in SL (bases of fin membranes not perforate); interdorsal space 1.3 in head length; base of pectoral fin below point slightly posterior to centre of eye; caudal fin length 1.3 in head length; all fin rays except those of caudal unbranched; pelvic fin rudiment non-mobile, moderate-sized (3.4 in eye diameter), consisting of 2 pairs of encasing scales fused to posterior end of pelvis, armed with small barbs (see Figure 2).

Scales on body small, armed with small, slender acute spinules which curve slightly posteriorly at extremities, giving a velvety feel; each mid-body scale possesses 2-3 transverse rows of spinules; scale outlines not visible to naked eye; caudal peduncle unarmed.

Colour of holotype in preservative (70% ethanol) (Figure 1): head and body pale brown with numerous dark brown spots, those on cheek relatively closely packed and tending to form curved lines, those on sides of body larger, more separated and forming 4-5 longitudinal series; 3 dark blotches on both soft dorsal and anal fin bases; a dark blotch surrounds anus; forehead crossed by U-shaped band at base of first dorsal spine and a V-shaped band anterior to it; all fins hyaline and unmarked except caudal which possesses 2 curved dark brown bands. Life colours unknown.

Remarks

Thamnaconus fijiensis so far is known only from the holotype collected at Fiji. Its closest relative is *T. fajardoi* (Figure 3) which inhabits seas off the East African coast, Madagascar and Mauritius at depths of 130-150 m. Both possess similar patterns of spotting, although considerably reduced on the body of *T. fijiensis* (see Figures 1 and 3). In addition, both have a dark blotch surrounding the anus, a U and V-shaped band across the forehead, and two curved bands across the caudal fin. They also possess the lowest elevated dorsal and anal fins of the genus, similar fin ray counts, and a first dorsal spine of almost identical structure. The main differences between the two lie in the degree of spotting on the body and the noticeably larger body scales of *T. fajardoi*. Thus it appears that *T. fijiensis* is most similar to *T. fajardoi*, even though there is a considerable geographical distance between the known ranges of the two. Perhaps, like *T. modestoides* which has recently been found in Australia (see Hutchins 1977) and Japan (see Zama and Yasuda 1979) as well as in South Africa, the distributions of these two species of *Thamnaconus* will be discovered, after more collecting in the intervening area, to be considerably closer together if not sympatric.

This species is named *fijiensis* with reference to the type locality.

Additional Material Examined

Thamnaconus fajardoi, 5 specimens, 79-179 mm SL: MNHN 1983-312, 79 mm SL, off Toliara (23°01'S, 43°26'E), Madagascar, 150 m, L. A. Mauge, 1 April 1969, MNHN 1983-315 to 317, 3 specimens, 152-179 mm SL, collected with previous specimen, BPBM 16309, 126 mm SL, off Grande Baie (20°00'S, 57°25'E), Mauritius, 130 m, J.E. Randall, 9 November, 1973.

Acknowledgements

We are grateful to M.L. Bauchot, Museum National d'Histoire Naturelle, Paris (MNHN), J. Seeto and U. Raj, USP and J.E. Randall, Bernice P. Bishop Museum, Honolulu (BPBM) for providing specimens on loan. The collection of the holotype of *Thamnaconus fijiensis* was made possible with funds provided by the European Economic Community to the Institute of Marine Resources at USP. We are particularly indebited to J. Seeto for bringing this specimen to our attention.

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A New Species of Freshwater Grunter (Pisces: Teraponidae) from New Guinea

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Abstract

A new species of teraponid, *Hephaestus lineatus*, is described from six specimens collected from freshwater streams on the Vogelkop Peninsula, Irian Jaya. It is closely related to *H. habbemai* (Weber) from south-central New Guinea and *H. trimaculatus* (Macleay) from the Port Moresby region, by a higher soft anal ray count and colour pattern.

Introduction

The family Teraponidae (Theraponidae of many authors) contains approximately 45 species and is confined to the Indo-west Pacific region. Aside from a few relatively widespread marine forms most species have evolved in freshwaters of Australia-New Guinea. This area is occupied by about 30 species belonging to nine genera.

The teraponid grunters of New Guinea were reviewed by Mees and Kailola (1977), who recognised seven marine or estuarine species and 12 from freshwater, including five new species. These authors placed all of the species in the genus *Therapon*. Vari (1978), however, gave sufficient evidence for dividing the family into 15 genera, seven of which have been recorded from New Guinea. The present paper describes a new species collected by the author during a visit to the Vogelkop Peninsula at the western extremity of New Guinea in November, 1982. It belongs to the genus *Hephaestus* De Vis as recognised by Vari (1978) which contains 11 species distributed in freshwater streams of northern Australia and New Guinea.

The format and terminology used in the description follow those of Vari (1978). Counts were recorded for all specimens, but only the two largest fish were utilised for proportional data. The range of counts for the paratypes is indicated in parentheses following the data for the holotype, but only proportional data for the largest (42.3 mm SL) paratype is presented in parentheses. Type specimens have been deposited at the National Institute of Biology (Lembaga Biologi Nasional), Bogor, Indonesia and the Western Australian Museum, Perth. The abbreviations LBN and WAM are used for these respective institutions in the subsequent text.

Systematics

Hephaestus lineatus sp. nov.

Figures 1 and 2

Holotype

LBN 4947, male, 86.5 mm SL, small stream at Fruata Village, Irian Jaya (approximately 2°59'S, 132°32'E), seine, G. Allen and H. Bleher, 16 November 1982.

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Figure 1 *Hephaestus lineatus,* holotype, 86.5 mm SL, Fruata, Irian Jaya.

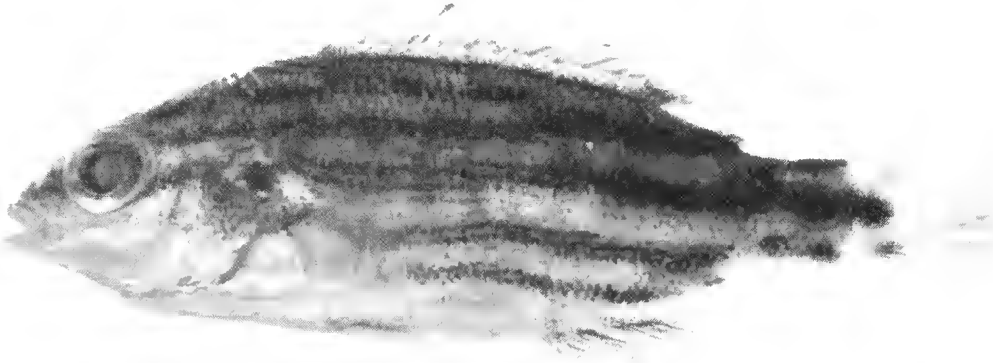

Figure 2 *Hephaestus lineatus,* juvenile paratype, 23.0 mm SL, Suswa, Irian Jaya.

Paratypes

LBN 4948, 2 specimens, 23.0-37.0 mm SL, stream at Merdai Village, Irian Jaya (approximately 1°35'S, 133°20'E), seine, G. Allen and H. Bleher, 16 November 1982; WAM P27868-002, 2 specimens, 22.0-23.0 mm SL, Auk River near Suswa Village, Irian Jaya (approximately 0°56'S, 132°15'E), seine, G. Allen and H. Bleher, 18 November 1982; WAM P27869-002, 42.3 mm SL, tributary stream of Kamundan River at Senopi Village, Irian Jaya (approximately 0°50'S, 132°56'E), seine, G. Allen and W. Tins, 18 November 1982.

Diagnosis

A species of the teraponid genus *Hephaestus* closely allied to *H. habbemai* (Weber) and *H. trimaculatus* (Macleay). It differs most notably from these two species on the basis of soft dorsal ray count (12-13 v. 10-11) and colour pattern, which consists of 5-6 longitudinal stripes on the side, narrower than intervening pale spaces, with a prominent semi-ocellated black spot on upper rear edge of operculum. In contrast the opercular spot is absent in the allied species. *Hephaestus habbemai* usually lacks stripes in mature adults with the smallest juveniles (under about 20-30 mm SL) having a pattern of five vertical bars superimposed on the 6-8 longitudinal stripes which are wider then the intervening spaces. *Hephaestus trimaculatus* generally possesses 7-8 stripes which are narrower than the intervening pale spaces.

Description

Dorsal rays XIII,12 (XIII,12 or 13); anal rays III,12 (III,12 or 13); pectoral rays 15 (14 to 16); pelvic rays I,5; tubed lateral-line scales 54 + 4 or 5 tubed scales on caudal fin base; scales above lateral line 7; scales below lateral line 17 (17 to 18); predorsal scales to occiput 16; sheath scale rows at base of dorsal fin 2; sheath scale rows at base of anal fin 3 to 5; scale rows on cheek 7; gill rakers on first arch 7 + 13 (6 to 8 + 13 or 14); vertebrae 11 + 16 = 27.

Body moderately deep for the family and laterally compressed, greatest depth 2.6 (2.8) in SL. Head relatively short with blunt snout, its length 3.0 (2.7) in SL. Distance from dorsal origin to snout 2.4 (2.3), length of base of dorsal fin 1.8 (1.9), both in SL. Snout length 3.0 (3.5), eye width 3.6 (3.1), jaw length 3.0 (3.9), length of longest dorsal spine 1.9 (2.1), length of longest soft dorsal ray 2.0 (2.2), length of longest anal spine 2.0 (2.2), and length of longest soft anal ray 1.7 (1.8), all in head length.

Dorsal profile gradually curving, more pronounced than ventral profile. Dorsal profile convex from snout to interorbital region, then slightly concave at interorbital, but nape convex to dorsal fin origin. Ventral profile curved from tip of lower jaw to pelvic fin origin, straight from pelvic base to anus. Jaws equal or upper only slightly longer. Gape oblique. Mouth slightly protractile. Posterior of maxillary reaching to level of anterior margin of pupil or slightly beyond. Teeth conical with brown tips, outer row much enlarged followed by a band of villiform teeth. Lower jaw with a median ventral gap in lip fold. Vomer and palatines without teeth. Nostrils separated by a distance about twice greatest diameter of posterior nostril. Lacrimal with several small serrations posteriorly. Preoperculum distinctly serrate. Lower opercular spine stronger and longer than other spines, not extending beyond edge of opercular lobe. Posttemporal exposed, but covered with skin, serrate posteriorly. Supracleithrum exposed, serrate posteriorly.

Spinous dorsal fin arched, the first spine very short, fifth to seventh spines longest, those following decreasing gradually in length to penultimate which is equal or slightly less than ultimate. Longest dorsal spine slightly longer than longest soft dorsal rays. Soft dorsal fin rounded. First anal spine about two-thirds length of second anal spine, which is much

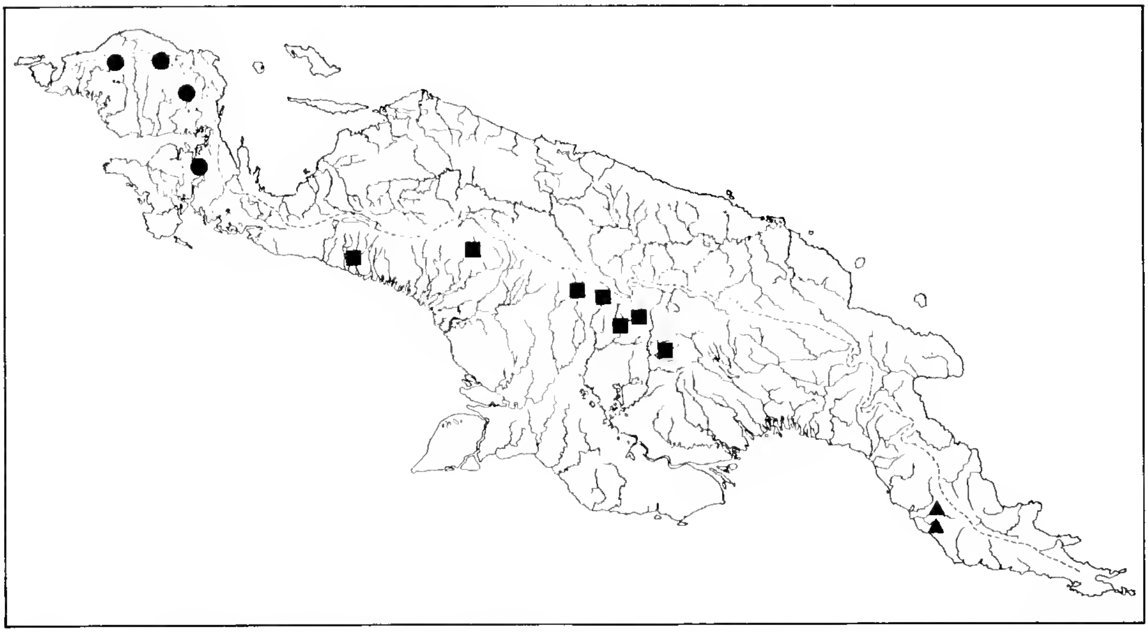

Figure 3 Map of New Guinea showing distribution of *Hephaestus lineatus* (circles), *H. habbemai* (squares), and *H. trimaculatus* (triangles).

stronger than third spine and shorter than longest soft anal rays. Pectoral fins pointed, fourth ray (from top) longest. Pelvic fins pointed, first soft ray longest and slightly filamentous, extending just beyond anus. Caudal fin emarginate.

Colour when fresh: holotype overall grey-brown, whitish on ventral portion of head, breast, and abdomen; a series of five faint, darker grey longitudinal stripes on side, stripes slightly narrower than intervening brownish areas; cheek and operculum brown; prominent, half-ocellated black spot on upper rear margin of operculum; fins light grey or slightly dusky-brown. Smallest (22.0-23.0 mm SL) paratypes generally whitish with five longitudinal stripes on side, these with dark grey or blackish margins and pale grey central area; lower half of head, breast, and abdomen silvery-white; fins translucent to slightly dusky; base of caudal fin with three blackish spots in vertical row; a prominent black spot on upper rear margin of operculum. The 42.3 mm SL paratype is similarly coloured except there is a sixth stripe positioned across the belly.

Colour in alcohol: similar to live coloration except stripes of holotype less conspicuous and ground colour of juveniles yellowish instead of white.

Remarks

Hephaestus lineatus is most closely related to *H. habbemai* (Weber) and *H. trimaculatus* (Macleay) as indicated in the above diagnosis. Vari (1978) placed *H. habbemai* in the synonymy of *H. trimaculatus*, but his analysis was based on relatively few specimens from a limited number of localities. I prefer to follow the separation of these species by Mees and Kailola (1977). They reported significant differences related to colour pattern and lateral-line scale counts. This species pair is confined to southern New Guinea *Hephaestus habbemai* is known from the Mimika and Lorentz Rivers of Irian Jaya and the Fly-Strickland system of Papua New Guinea. It generally inhabits headwater streams in hilly terrain. *Hephaestus*

Table 1 Fin ray and gill raker counts for *Hephaestus lineatus*.

Soft dorsal rays	
12	13
5	1

Soft anal rays	
12	13
4	2

Pectoral rays		
14	15	16
2	3	1

Gill rakers				
upper limb			lower limb	
6	7	8	13	14
3	2	1	4	2

trimaculatus is known from the Laloki River and its tributaries, the Goldie and Brown Rivers, in the general vicinity of Port Moresby. During the 1982 expedition *H. lineatus* was collected or observed underwater at a number of widespread localities on the Vogelkop Peninsula of Irian Jaya. The known distributions for this species and its nearest allies are indicated on the map in Figure 3.

The habitat generally consists of moderate flowing, clear rivers and creeks with pH and temperatures ranging between 7.4-8.5, and 24°-29°C respectively.

The name *lineatus* (Latin: 'striped or lined') refers to the characteristic colour pattern.

Acknowledgements

I am indebted to Mr Heiko Bleher and Mr Hans Mayland of Frankfurt, Germany for providing financial assistance for the 1982 visit to Irian Jaya. Mr Bleher and Mr Wolfgang Tins of Munich assisted with field collections on the Vogelkop Peninsula. Dr Walter Ivantsoff of Macquarie University (Sydney) generously provided radiographs utilised for the vertebral counts. I also thank Mr Allan Williams for the photographs and Mrs Connie Allen for her careful preparation of the typescript.

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Relationships of *Tympanocryptis aurita* Storr, 1981

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Abstract

Several characters of *Tympanocryptis aurita* Storr, 1981 indicate a closer relationship to *Ctenophorus* than to *Tympanocryptis*. However, it possesses other features not present in *Ctenophorus*, and thus should not be placed in that genus. The genus *Cryptagama* is erected to accommodate the species.

Introduction

Storr (1981) described *Tympanocryptis aurita*, so named because of its possession of a tympanum. True *Tympanocryptis* (*sensu* Mitchell 1965) are characterised by a reduced pes phalangeal formula (Cogger 1961; Mitchell 1965), and by the loss of a functional tympanic membrane (Witten 1982a, 1982b). The description of *Tympanocryptis aurita* contradicts the second of these features and Storr did not present data on the first. These and other morphological features were examined in order to determine the relationships of *Tympanocryptis aurita*.

Results

Gross examination of specimens of *Tympanocryptis aurita* revealed that they possess the full pes phalangeal formula typical of the majority of Australian agamids. This has been confirmed with the use of x-rays (Cogger, pers. comm.). Pore morphology, the structure of the labial scales, and the relatively small scales of *Tympanocryptis aurita* also indicate that the species is only distantly related to *Tympanocryptis*. However, the animal is not clearly related to any other agamid genus, necessitating the description of a new genus:

Systematics

Cryptagama gen. nov.

Type Species

Tympanocryptis aurita Storr, 1981: 599-602. Figures 1 and 2.

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Diagnosis

Limbs and tail short, the tail shorter than snout-vent length. Canthus rostralis absent. Femoral pores in widely spaced series on middle to posterior part of lower surface of thigh, each pore penetrating a scale. Enlarged tubercles scattered across entire dorsal surface, extending onto limbs and tail. Supralabial scales forming denticulate fringe along upper lip. Scales very small, mid-body scale count 140-164. Tympanum large and superficial. Pes phalangeal formula 2.3.4.5.4.

Etymology

The generic name comes from the Greek *kryptos* meaning hidden or secret and the type genus of the family, *Agama.*

Cryptagama aurita (Storr, 1981)

Tympanocryptis aurita Storr, 1981.

Description

The following notes should be considered as additional to those of Storr (1981). The holotype is a mature female. A number of ovarian follicles are present, and the oviduct is opaque and convoluted, possibly indicating previous reproductive activity. The nostril opens almost vertically from the oblique circular opening on the swollen nasal. The pores are very small and a full pore count was not possible. There are about 11 pores in the larger paratype (R64052) and at least 5 in the smaller (R64051). There are 16-17 infralabial scales.

Discussion

Cryptagama almost certainly represents, with *Tympanocryptis cephalus,* a case of parallel evolution. *Tympanocryptis cephalus* is remarkably similar in general appearance, but differs from *Cryptagama* in a number of important characters. *Tympanocryptis cephalus* has a reduced phalangeal formula (Cogger 1961: Mitchell 1965) and has no functional tympanum (Witten 1982a). All members of the *Tympanocryptis* group (genus *Tympanocryptis sensu* Storr 1982; including *T. adelaidensis* and *T. diemensis*) have pores between scales and labials which are longer than deep (Witten 1982a), characters not present in *Cryptagama.*

The removal of *aurita* from *Tympanocryptis* does not affect the definition of the genus given by Storr (1982). The intrascalar pores of *Cryptagama* do not agree with Storr's description of 'each located between 3-5 scales'. Storr's definition of *Tympanocryptis* should be expanded to include the possession of elongate labials, a further character distinguishing *Cryptagama* from it. It should also be pointed out that pores are usually present in female *Tympanocryptis,* although not active. The interscalar position of pores in *Tympanocryptis* makes inactive pores particularly difficult to detect.

The nearest relatives to *Cryptagama* are probably within *Ctenophorus. Ctenophorus* and *Pogona* do not have elongate labial scales and often possess posterior intrascalar pores (pores opening on or near the posterior margin of a scale; Witten 1982a). Both these features, shared with *Cryptagama,* appear to be reliable phylogenetic indicators within the Australian agamids (Witten 1982a). This relationship is supported by data on scale size. All *Tympanocryptis* have mid-body scale counts below 100 (Witten 1982a). *Cryptagama* has up to 164 (holotype), a figure attained elsewhere in the Australian endemic agamids only by some individuals of *Ctenophorus ornatus, Pogona barbata* and *Moloch horridus* (Witten 1982a).

Storr's (1982) definition of *Ctenophorus* includes the description '. . . pores, each located between 4 scales (anterior usually largest)'. This appearance in most *Ctenophorus* is produced by the pore penetrating the posterior margin of a scale, although some *Ctenophorus* do have interscalar pores (Witten 1982a). Storr's definition of *Ctenophorus* should therefore be modified slightly to include both posterior intrascalar pores and interscalar pores.

Although *Cryptagama* appears to be related to *Ctenophorus* and *Pogona* several morphological features suggest it should not be included in *Ctenophorus.* The upper labial 'fringe' of *Cryptagama* is unique among Australian agamids. Only *Moloch* shares the possession of a tail shorter than its snout-vent length. Further, the adaptation of *Cryptagama* to a cryptozoic habit has resulted in a dorsal surface unlike any species of *Ctenophorus.*

Acknowledgements

The co-operation of G.M. Storr, H.G. Cogger and A.J. Coventry is gratefully acknowledged for providing access to the type series of *Tympanocryptis aurita.* Helpful suggestions were made by H.G. Cogger and A.J. Coventry. The manuscript was typed by Gail Birchall.

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A Redescription of the Rare Echinoid *Taimanawa mortenseni* Henderson and Fell (Spatangoida: Brissidae)

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Abstract

The only living species of the brissid *Taimanawa, T. mortenseni* Henderson and Fell, 1969, is redescribed from the first known complete specimen, collected recently from the outer North-West Shelf, Western Australia. Previously the species was known only from two broken fragments collected off the Kei Islands, Indonesia.

Introduction

Henderson and Fell (1969) erected the genus *Taimanawa* for two fossil and one living species of large spatangoids characterised by the possession of subanal, peripetalous and internal fascioles, primary tubercles confined to the posterior plate series of the paired interambulacra and a deep anterior notch. Four fossil species of *Taimanawa* are known from New Zealand: *T. pulchella* Henderson and Fell, 1969, from the Early-Middle Miocene; *T. greyi* (Hutton, 1870) from the Oligocene-Early Miocene; *T. prisca* Henderson, 1975, from the Late Eocene; and *T. rostrata* Henderson, 1975, from the Late Oligocene-Early Miocene.

The two fragmentary specimens upon which Henderson and Fell (1969) erected *T. mortenseni* were collected from off the Kei Islands, Indonesia, in 260 m of water. Mortensen (1951) had earlier been uncertain of the taxonomic position of the fragments, questioningly placing them in *Plagiobrissus*.

In August 1983, during trawling on the outer North-West Shelf of Western Australia by the 'FV Courageous', a single, complete test attributable to *T. mortenseni* was recovered. Associated spatangoids from this region include *Lovenia gregalis* Alcock, 1893, *Lovenia* sp. nov. and *Pericosmus porphyrocardius* McNamara, 1984. This paper provides the first full description of *T. mortenseni,*

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and documents the nature of the labrum, phyllode, adoral plating, posterior of the adoral surface of the test, spines and pedicellariae, which hitherto were unknown.

Measurements on the specimen were carried out using a vernier calliper to a precision of ± 0.1 mm. Relative sizes of features of the test are expressed as percentages of test length (%TL).

Systematics

Order Spatangoida Claus, 1876
Family Brissidae Gray, 1855

Remarks

Although *Taimanawa* possesses an internal fasciole, Henderson and Fell (1969) did not place it in the Loveniidae even though this family is characterised by the possession of an internal fasciole (Mortensen 1951). The genus *Breynia*, which has the three same fascioles, is placed in the Loveniidae. Henderson and Fell (1969) considered that *Taimanawa* is more closely related to a number of brissid genera, such as *Gillechinus* and *Plagiobrissus*, in particular, as it has long, narrow petals, a short labrum, crenulate tubercles, and lacks ampullae. The specimen described below provides nothing to suggest that, internal fasciole apart, *Taimanawa* should be placed in the Loveniidae. On the contrary, the presence of a long, narrow, parallel-sided plastron is far more in keeping with its placement in the Brissidae rather than in the Loveniidae. The presence of an internal fasciole further highlights the problem of using fascioles to provide a familial subdivision of spatangoids. The present, generally unsatisfactory, suprageneric, classification of spatangoids is based largely on the common occurrence of certain types of fascioles. Some problems with this approach have recently been discussed by McNamara and Philip (1980).

Genus *Taimanawa* Henderson and Fell, 1969

Type Species

T. pulchella Henderson and Fell, 1969: 3; by original designation.

Taimanawa mortenseni Henderson and Fell, 1969

Figures 1-4

Plagiobrissus sp. ? – Mortensen 1951: 503, p1.39, fig. 3.
Taimanawa mortenseni Henderson and Fell, 1969: 12-14, p1.5, fig. 1; – Henderson 1975: 47.

Material

The holotype and paratype (University Zoological Museum, Copenhagen) were collected from Station 32 of the Danish Expedition to the Kei Islands in 1922. The single specimen described here (WAM 43-84), the only other specimen known, was collected from the North-West Shelf north-east of Rowley Shoals at 16°56'S, 120°06'E, from a depth of 431 m on 20th August, 1983 by P. Berry and N. Sinclair. Sediment associated with the specimen consists of a foraminiferal-rich mud.

Diagnosis

Anterior notch very deep and narrow; 23 well-developed pore pairs in anterior petals and 13-15 weakly crenulate primary tubercles in each of the paired interambulacra.

Description

Test large, 150 mm long; low; maximum height 43% TL, situated at apical system, which is 37% TL from anterior notch; ethmolytic, with four genital pores. Test widest at about mid-test length, width 92% TL. Anterior notch very deep, 10% TL, and narrow. Anterior ambulacrum barely sunken for adapical two-thirds of its course, then deepens rapidly adambitally. Internal fasciole narrow; 15% TL wide across apical system, extending one-third of length of anterior ambulacrum before disappearing; irregular and broken anteriorly. Peripetalous fasciole 69% TL wide at its widest point, slightly anterior of apical system. Anterior petals diverge at about 130°; slightly sinuous; sunken; reaching a maximum width of 5% TL at about half length; total length 33% TL; poriferous zones sub-parallel between fascioles, diminishing rapidly in width adapically, as pore pairs become very small; 23 non-conjugate pore pairs present between fascioles. Posterior petals diverge at about 55°; slightly shorter than anterior pair, being 30% TL long; possessing 21 pore pairs between fascioles; straight and nearly parallel; narrow close to internal fasciole, as pore pairs diminish in size. Posterior plate series of paired interambulacra possess 13-15 primary tubercles set in depressed embayment; tubercles perforate; very weakly crenulate with wide scrobicules. Anterior plate series of interambulacra 2 and 3 bear secondary tubercles close to anterior ambulacrum. Primary spines up to 43 mm in length; secondary spines up to 15 mm in length. Dense miliary spines fine and hair-like, up to 5 mm in length (Figure 1).

Anteriorly situated peristome slightly sunken; only 12% TL from anterior notch; 14% TL wide; only 2% long, as the short labrum projects strongly forward two-thirds of the way across peristome (Figure 2). Phyllode with 11 unipores in ambulacra II and IV; 7 in ambulacrum III; 6-7 in ambulacra I and V. Large periporal areas generally flattened, with slightly raised lateral lips. Adambitally, outermost phyllodal plates have slightly swollen periporal areas (Figure 3). Phyllodal tube feet black (on dried specimen); large; penicillate; discs with papillae, up to 5.5 mm wide (Figure 3). Plastron nearly parallel-sided; narrow, 28% TL; forming a keel, which intensifies adambitally. Periplastronal areas up to 15% TL in width; along with lateral interambulacra, relatively flat. Plate 2 of interambulacrum 1b does not bisect plate 1 and plate 2 of interambulacrum 1a. Subanal fasciole narrowly reniform, width 30% TL; encloses 5 pore pairs in ambulacrum I, and 6 in ambulacrum V. Periproct sunken, circular, diameter 10% TL.

Only two forms of tridentate pedicellariae are present; long and slender (Figure 4), and triangular-shaped with broad, spatulate distal terminations (Figure 4). The slender form reaches a length of 1 mm and is about five times as long as broad, the valves lengthening as the pedicellariae grow. In very small specimens

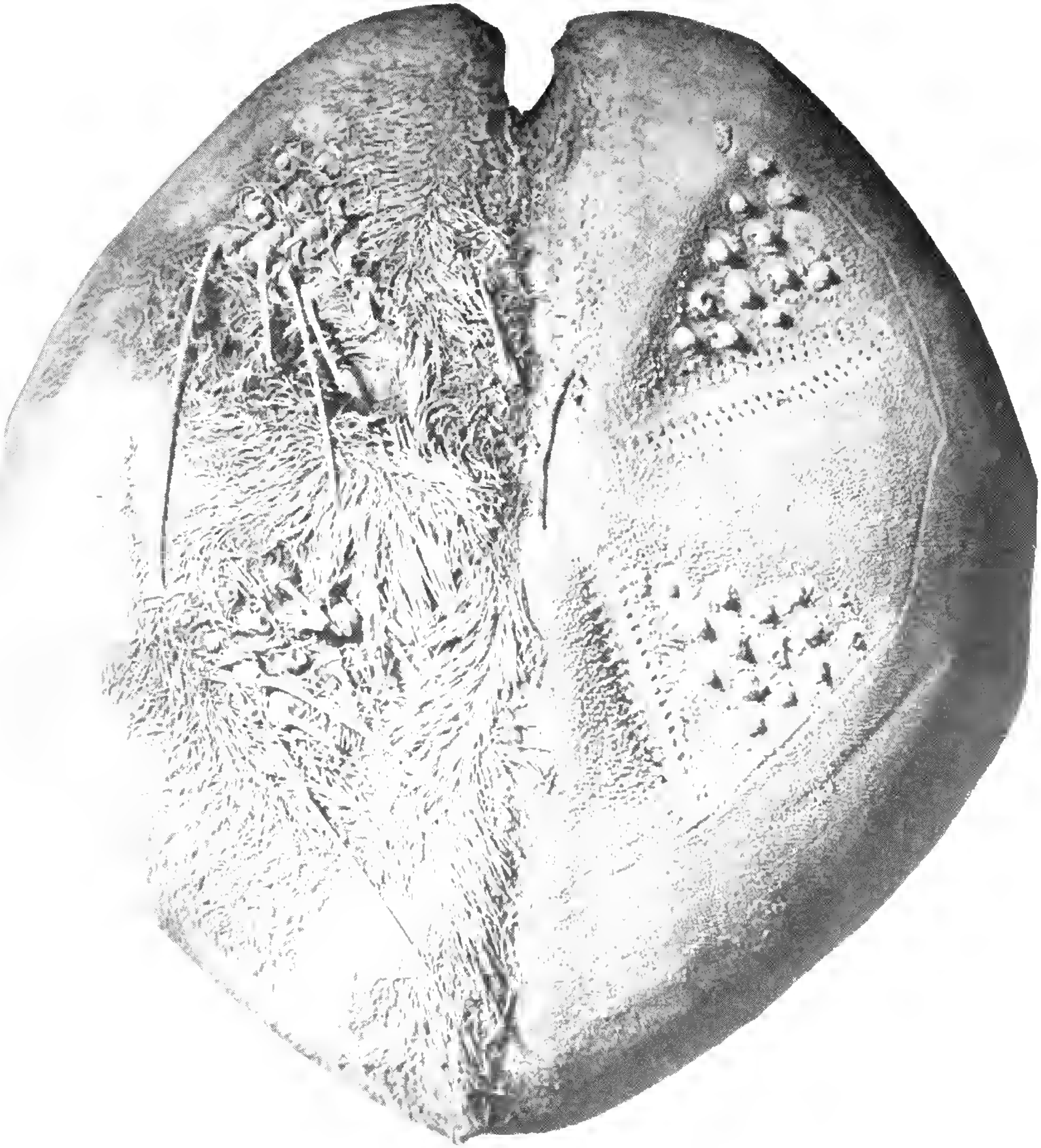

Figure 1 Aboral view of *Taimanawa mortenseni*, WAM 43-84, x 1.

the long, slender spatulate termination arises directly from the swollen base. With growth a thin shaft develops which may exceed the length of the spatulate termination and bear up to six irregularly positioned, double pointed denticles (Figure 4). The long, spatulate termination is edged by about 60 small (5μ long) interdigitating denticles (Figure 4). The broad tridentate pedicellariae are only half as long again as broad. Each valve has a broad spatulate termination about

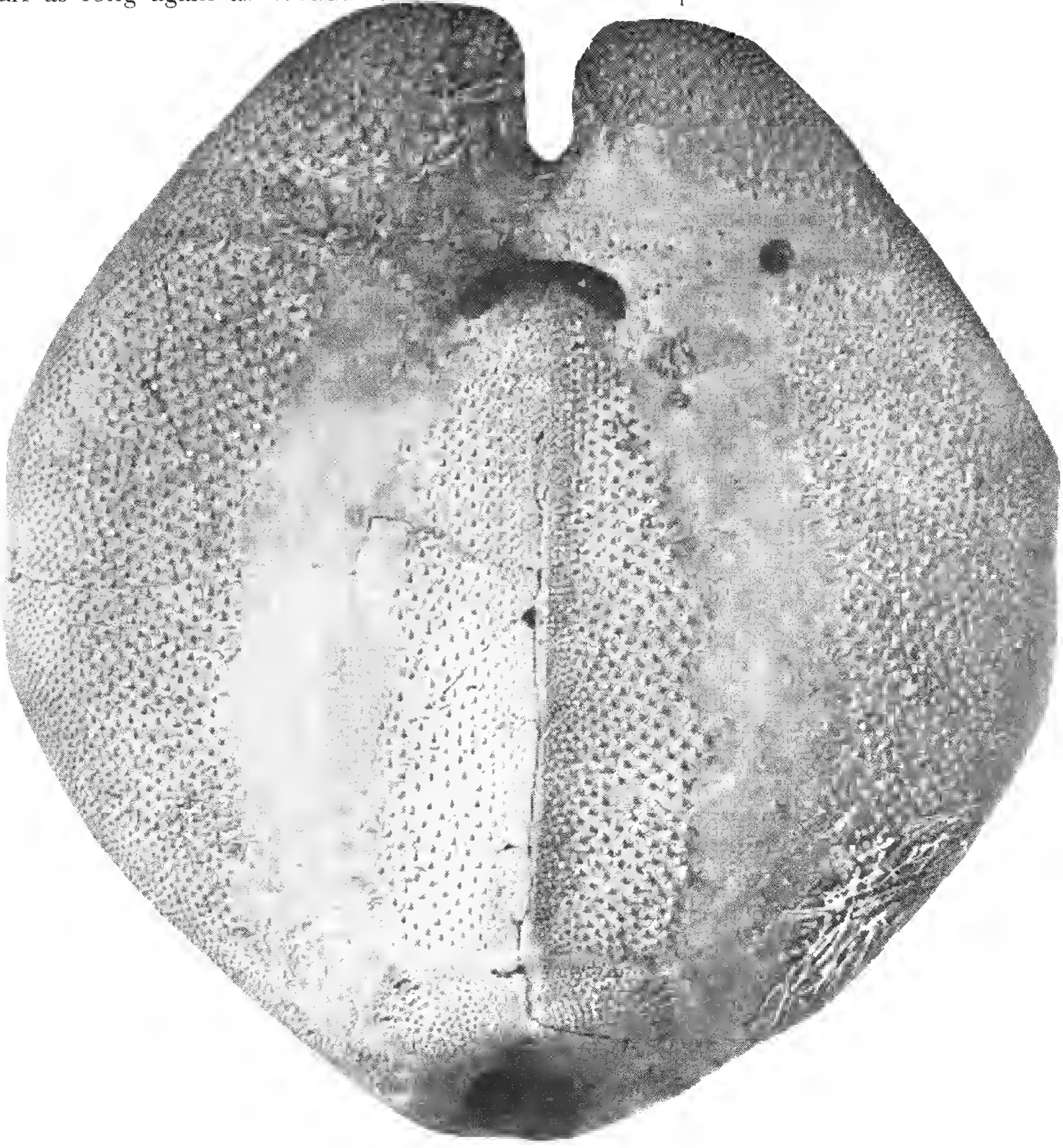

Figure 2 Adoral view of *Taimanawa mortenseni*, WAM 43-84, x 1.

two-thirds the width of the swollen base. It is tipped by a fine spine, and has finely denticulate edges. Near its base it may carry one or two large denticles. The broad form is confined to the aboral surface, whereas the slender form is more numerous and occurs over the entire test.

Remarks

Even though the type material is so fragmentary, there seems little reason to doubt that WAM 43-84 should be assigned to *T. mortenseni*. The North-West Shelf specimen and the holotype from the Kei Islands were collected about 1800 km apart. Both have a similar number of primary tubercles in the anterior paired interambulacra. There is a slight difference in the number of pore pairs in the anterior petals, 23 in WAM 43-84, 25 in the holotype. However, *T. greyi* shows a similar range of variations in this character (Henderson and Fell 1969: 11). The anterior of the holotype is damaged, but, like WAM 43-84, it seems to have possessed a very deep anterior notch. Both specimens are very large.

T. mortenseni can be distinguished from the four New Zealand fossil species by its larger size, longer petals, deeper anterior notch and less strongly crenulate

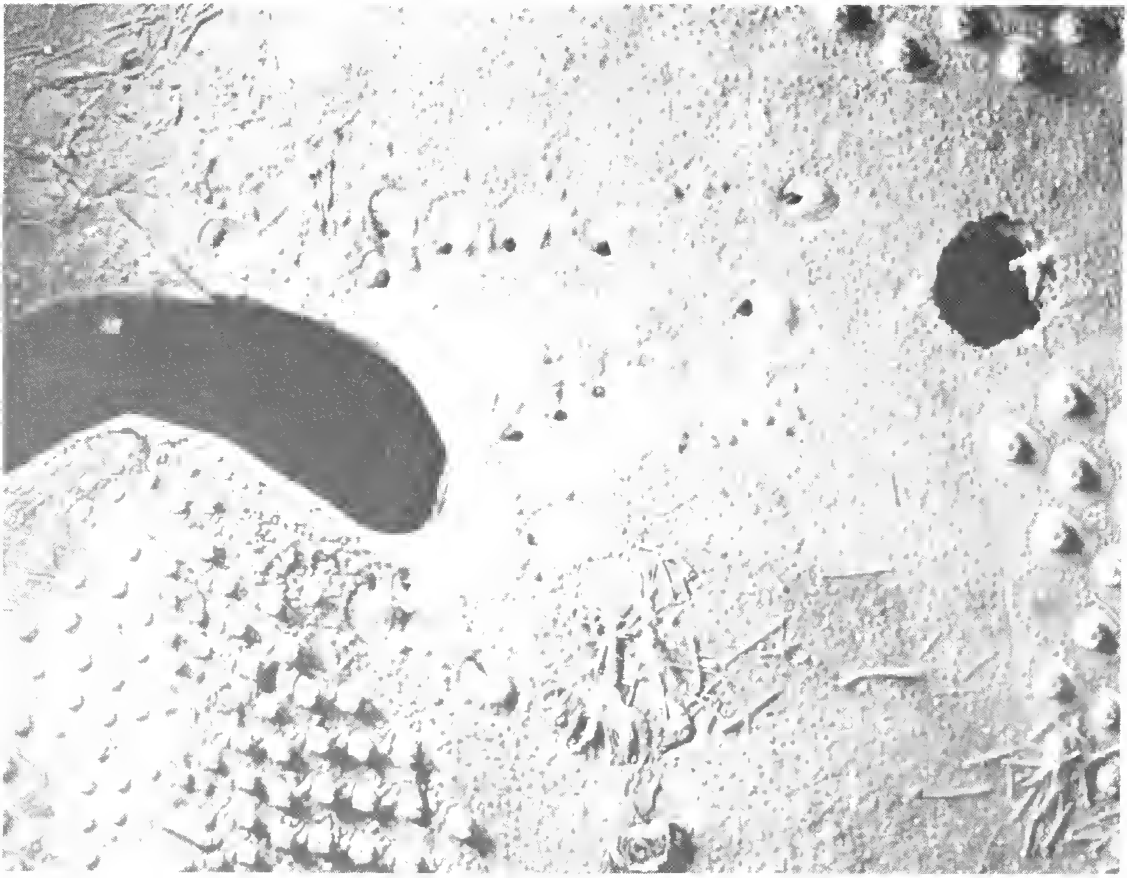

Figure 3 *Taimanawa mortenseni:* phyllodal pores in ambulacrum IV; note also a dried phyllodal tube foot; x 4.

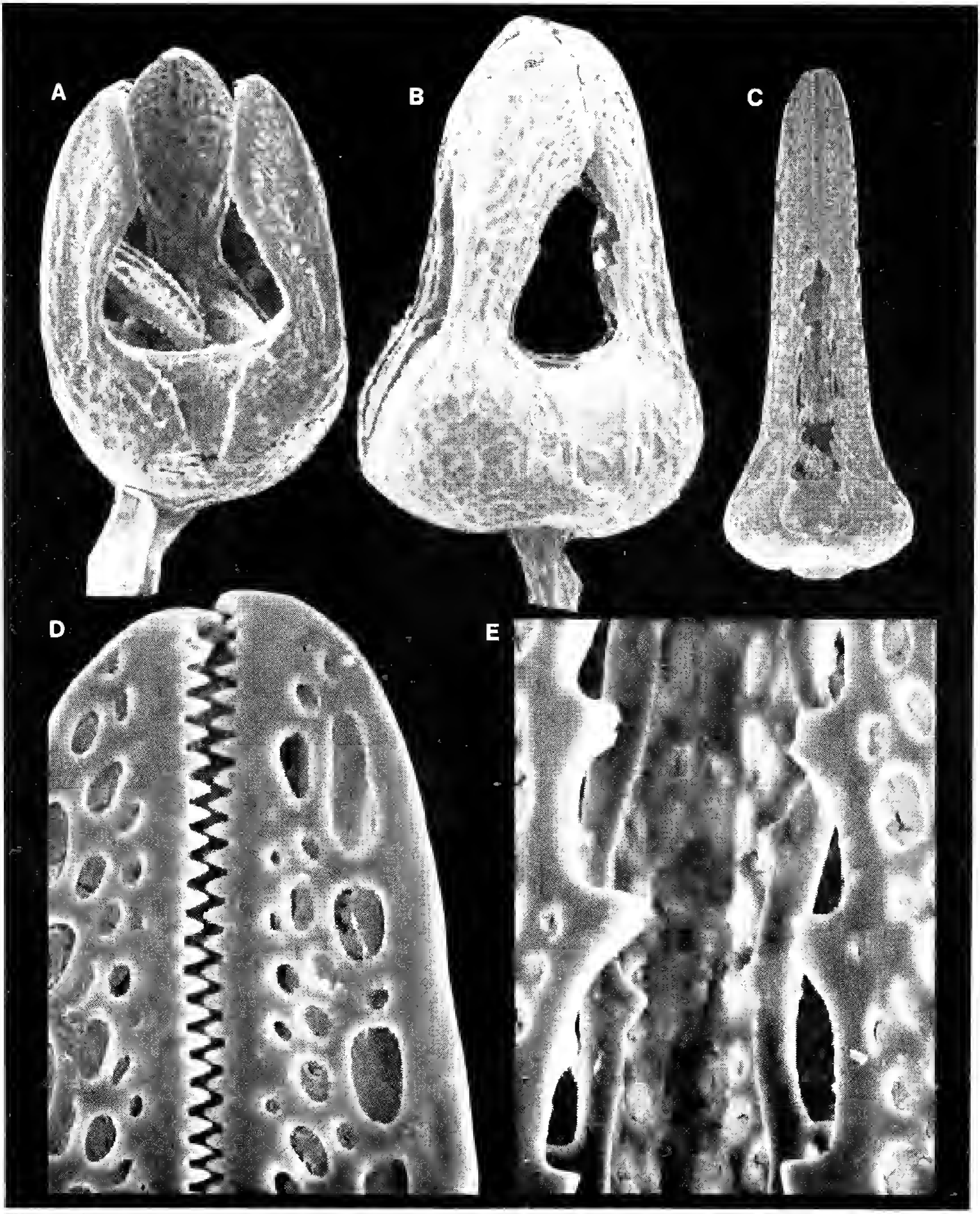

Figure 4 Pedicellariae of *Taimanawa mortenseni:* A (x90) and B (x110), broad tridentate form; C (x100), slender tridentate form; D (x750), enlargement of apex of C; E (x750), enlargement of denticles on shaft of C.

primary tubercles. It differs most from the oldest known species, the Late Eocene *T. prisca,* which is a much smaller form, with fewer primary tubercles and a much shallower, wider anterior notch. This species is close to *Gillechinus,* which is its presumed ancestor (Henderson and Fell 1969), essentially differing only in its possession of an internal fasciole. The three Oligocene-Miocene species are morphologically much closer to *T. mortenseni.* The youngest species, the Early-Middle Miocene *T. pulchella,* is, not surprisingly, most similar to *T. mortenseni,* differing only in its shallower anterior notch and shorter petals, with fewer pore pairs. In addition to its deeper anterior notch, *T. mortenseni* differs from *T. greyi* in its more anteriorly positioned apical system and fewer primary tubercles, and from *T. rostrata* in its longer petals and more numerous pore pairs in the paired petals.

The North-West Shelf specimen has a prominent circular hole in the anterior of the adoral surface of the test. A specimen of *T. pulchella* has a similar hole (Henderson and Fell 1969: 8). Both were probably attacked and killed by predatory gastropods. WAM 43-84, when collected, was covered by a large number of specimens of the lysianassoid amphipod *Scopelocheirus* (J. Lowry, pers. comm.), which were probably scavenging a recently killed individual. The trawl which contained the material from the North-West Shelf was capable of penetrating only slightly into the sediment. The recovery of only a single, dead test suggests the possibility that the living *Taimanawa* is a relatively deep burrower which escapes being picked up by a trawl which barely penetrates into the sediment.

Although Henderson and Fell (1969) considered the fossil species to be shallow water inhabitants, the living species is a moderately deep water, outer shelf species, having been collected from between 260 and 431 m.

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Observations on the Light-Sensitive Tube Feet of the Burrowing Echinoid *Protenaster australis* (Gray, 1851)

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Abstract

Observations made on the burrowing spatangoid echinoid *Protenaster australis* (Gray, 1851) have revealed that it possesses light-sensitive tube feet. These have not previously been reported in irregular echinoids. At a white-light intensity of 8500-9000 lux the tube feet in ambulacrum III undergo positive phototaxis. Ambital sensory tube feet and phyllodal feeding tube feet also respond to light at this level of illumination, but undergo negative phototaxis. The same phototactic responses were observed with illumination by blue and green light, but not with red or yellow light in all three types of tube feet. The tube feet in ambulacrum III remain positively phototactic until a level of illumination of about 150-175,000 lux, whereupon they become negatively phototactic. It is considered that these tube feet play an important role in ensuring that the echinoid test remains completely covered by sediment during daylight. Night emergence of some spatangoids, such as *P. australis*, may be partly due to a lack of stimulation of light-sensitive tube feet.

Introduction

Tube feet, the external expression of the water vascular system in echinoderms, attain their greatest morphological and functional diversity in spatangoid echinoids. Tube feet on different parts of the test of an individual spatangoid may be adapted to a wide variety of functions. They may be respiratory or sensory, or they may be mucus-secreting and used for either feeding or funnel construction or both (Nichols 1959a, b; Chesher 1963; Smith 1980). Sensory tube feet in irregular echinoids have been ascribed either a chemosensory or a tactile function (Nichols 1962). On the spatangoid test sensory tube feet occur either adorally, in the periplastronal areas; ambitally, between the petals and phyllode; or, in some shallow-burrowing spatangoids, aborally in ambulacrum III (Nichols 1959c). Light-sensitive tube feet have been recorded in some regular echinoids, namely *Arbacia punctulata* (Holmes 1912), *Diadema antillarum* (Millot 1954), *Psammechinus miliaris* (Millott and Yoshida 1956) and *Lytechinus variegatus* (Millott 1955,

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1956). However, light sensitivity has not previously been reported in the tube feet of any irregular echinoids. It is the aim of this paper to report for the first time the presence of light-sensitive tube feet in an irregular echinoid and to discuss the functional significance of this particular sense to burrowing echinoids.

Materials and Methods

Protenaster australis is an uncommon echinoid which has been collected on the coasts of northern Tasmania (Gray 1851), Victoria (Clark 1946), South Australia (Cotten and Godfrey 1942) and south-western Australia (Clark 1938, 1946; McNamara in press). Until two specimens were collected *in situ* in January 1983 (McNamara and Bryce 1983) details of the natural habitat of this echinoid were not well known. Data with specimens in the collection of the Western Australian Museum indicate that the species inhabits depths from 25 fathoms off Mandurah, to intertidal sand, in Bunker Bay, where a specimen was found buried in sand amongst rocks, *Zostra* and *Cymadocea.*

The specimens collected in 1983 were found off Trigg Beach, Perth, Western Australia, only 30 m from shore living buried to a depth of 10 cm in fine calcareous sand in a pocket on a limestone reef platform. The water depth was only 1.8 m. The reef platform is exposed at low tides, but covered by about one metre of water at normal high tides. After transferal to an aquarium these two specimens survived for only a couple of days.

In January 1984, three further specimens were collected from the same sand pocket. They were buried with their apices just below the sediment/water interface. Prior to collection the burrowing activity of the echinoids was observed and a series of photographs recording their behaviour was taken. During observations of their behaviour following their removal to an aquarium, it was noticed that some of the tube feet responded to increasing levels of illumination. In order to study the response of the tube feet to varying levels of light intensity the echinoids were placed close to the side of an aquarium on a thin layer of fine-grained calcareous sand and illuminated from a distance of 3 cm with a white, cold-light source produced by a 150 watt Volpi Intralux fibre-optic light unit. Light intensity was varied from 0 to 200,000 lux by means of a diaphragm attached to the light unit. Variations in light intensity were measured using a light meter placed 3 cm from the source of the illumination.

Analysis of the effect of changing light intensity was initiated when the echinoid was at a low level of ambient illumination and was relaxed and actively feeding on the sediment surface, sensory and feeding tube-feet being extruded and active. Observations were made on two individuals more than twenty times and consistent reactions were noted. The main tube feet of concern were the aboral tube feet in ambulacrum III although observations were also made on the phyllodal and ambital tube feet. The tube feet in ambulacrum III, like all others in *P. australis,* are pale reddish-purple in colour, with closely spaced transverse darker

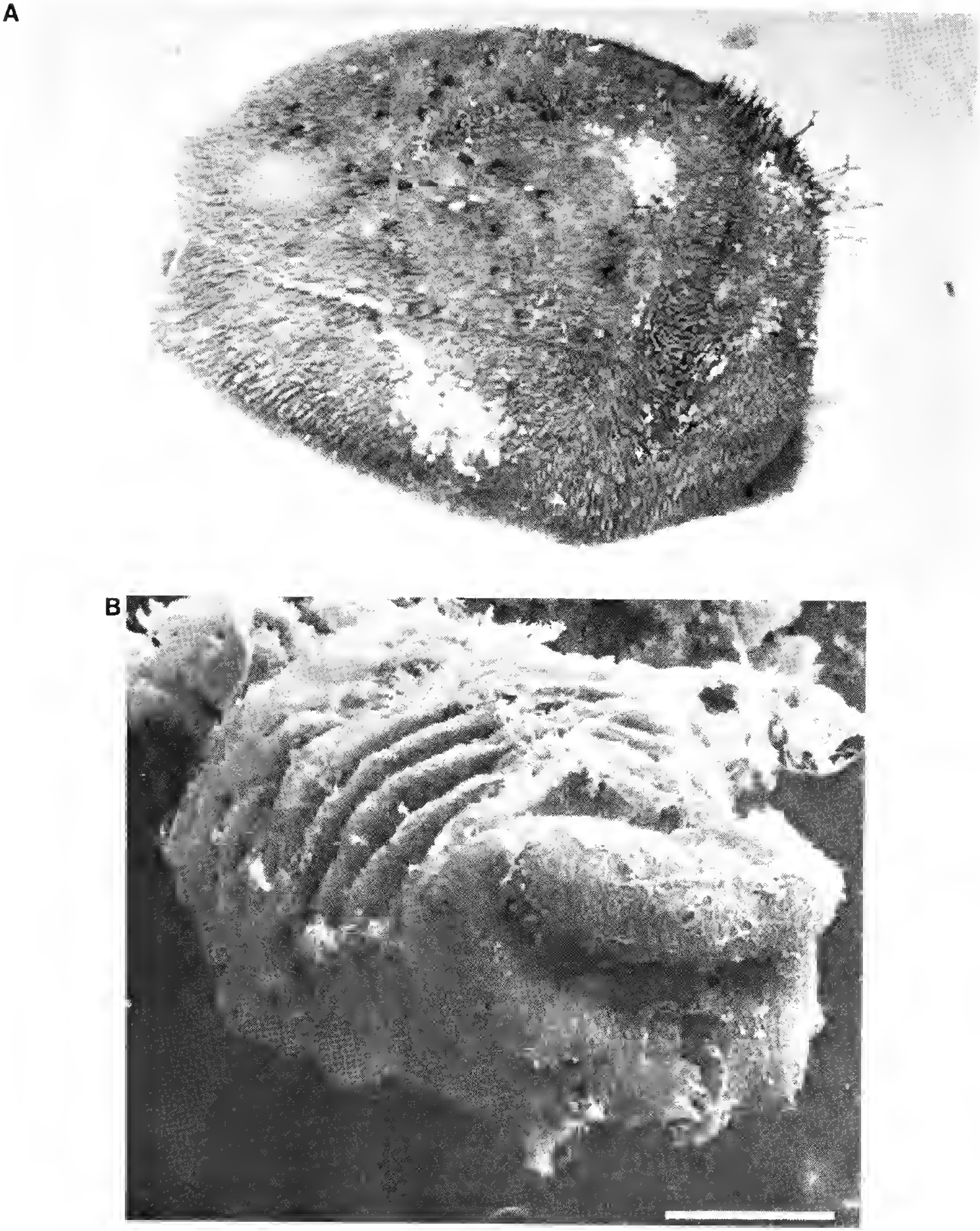

Figure 1 Light-sensitive tube feet in aboral ambulacrum III of *Protenaster australis* (Gray, 1851): (A) individual about twice natural size, photographed during daylight in water 1.8 m deep immediately after exhumation from the sediment and prior to burial. Note the positive phototactic response of the tube feet; (B) scanning electron micrograph of a freeze-dried tube foot from ambulacrum III in retracted condition. Note the simple light-sensitive terminal pad; bar equals 100μ.

bands. They occur in the slightly sunken ambulacrum III between the apical system and the peripetalous fasciole. Each tube foot possesses a terminal pad (Figure 1B) which is half as wide again as the tube foot and has a dark reddish-purple outer-rim. The tube feet are extensile, extending up to about 20 mm in length in specimens 80 mm in test length, and are longest adapically. The associated pore pairs in ambulacrum III are isopores, separated by a prominent, raised interporal partition, and do not diminish appreciably in size adambitally.

It was only possible to keep the echinoids alive in the aquarium for one week, thus observations over an extended period were not possible. This species is an uncommon echinoid and subsequent attempts to locate further specimens have been unsuccessful. However, the consistent reactions which were repeatedly observed in the two specimens indicate that should further specimens be found, similar results to those described below are likely to be obtained.

Results

The light source was placed to one side of the test, pointing at the tube feet in ambulacrum III. When extruded at low levels of ambient illumination the tube feet were observed to move continuously in a random motion. The light intensity was gradually increased, until the tube feet were all observed to undergo a positive phototactic response. This occurred at a level of about 8500-9000 lux. The tube feet turned to the source of illumination by bending their top one-third, the lower section remaining nearly perpendicular to the test surface. The tube feet remained active, but continued to point toward the source of illumination for as long as it remained above 8500-9000 lux. On moving the light source to the front of the echinoid test and then to the opposite side, the tube feet followed the light source. Increasing the light intensity resulted in the tube feet becoming more agitated. They continued to point at the light source until a reading of 150,000-175,000 lux was reached, whereupon the tube feet retracted. Following the removal of the source of illumination the tube feet re-emerged almost immediately. However, after repeating the illumination three or four times in quick succession, tube feet re-emergence took longer. Response at the lower and upper light levels was relatively rapid, occurring in less than one second.

The adoral phyllodal tube feet and the ambital sensory tube feet were also subjected to illumination and found to be light sensitive. The mucus-generating penicillate tube feet of the phyllode (Figure 2) actively pick up the fine sediment and pass it to the mouth. The ambital tube feet simultaneously touch the sediment in front of the phyllode, either reacting to tactile or chemosensory stimuli. Although not possessing a terminal pad, the ambital tube feet also responded to light at the same threshold level of 8500-9000 lux as those in the aboral part of ambulacrum III. Moore (1921) considered that in echinoderms only those tube feet with a terminal pad are photosensitive. Clearly, this is not the case in *Protenaster*. Unlike the adapical tube feet the ambital tube feet displayed negative phototaxis, initially curling their apices into a spiral, and then withdrawing rapidly. The phyllodal tube feet likewise underwent negative phototaxis at this same threshold level and withdrew and ceased feeding. Positive phototaxis by the aboral tube feet in ambulacrum III did not cause any reciprocal response to the adoral and ambital tube feet. However, there was a marked increase in activity of the ambital and adoral interambulacral burrowing spines and the echinoid began burrowing into the sediment. With prolonged exposure to light above 8500-9000 lux the peripetalous fasciole secreted mucus in preparation for burrowing. A series of photographs taken of the echinoids *in situ* prior to collection shows that during burrowing activity the tube feet of ambulacrum III remain fully extended while exposed and show a positive phototactic response (Figure 1A).

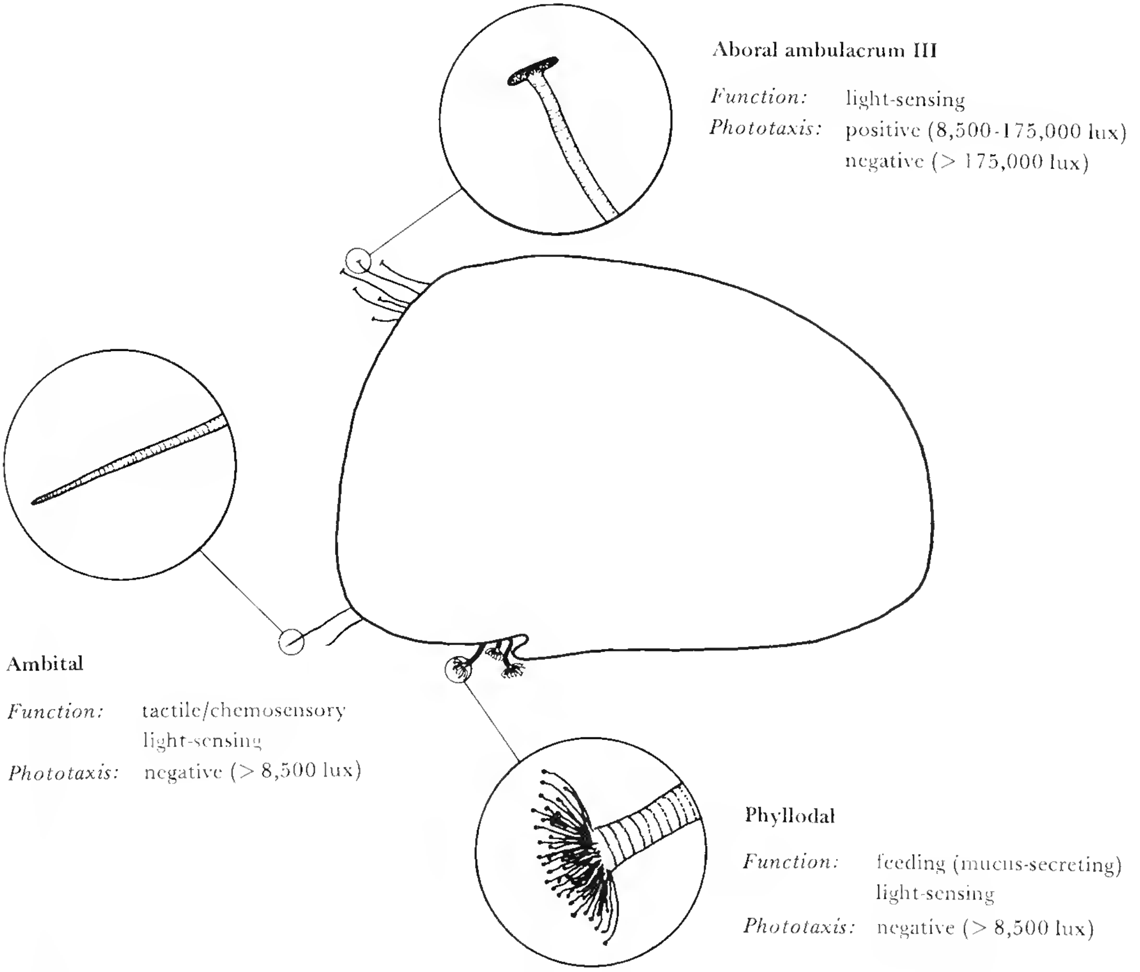

Figure 2 Outline of the test of *Protenaster australis* (Gray, 1851) showing distribution and detail of the three forms of light-sensitive tube feet. Test approximately natural size, expanded tube feet approximately x 10.

In addition to observing the responses of the tube feet to white light, blue, green, red and yellow filters were placed in front of the light source in order to assess the reaction of the tube feet to light of different wave lengths. When illuminated with blue and green light, the tube feet responded in the same manner as they did with white light, and at the same light intensities. However, illumination with red and yellow light elicited no response. The reaction to only blue and green light is not surprising as blue and blue-green light penetrates water most effectively (Utterbach 1936). The tube feet of *Psammechinus miliaris* react most strongly to blue-green light (Millott and Yoshida 1956). Although not specifically analysed, it would seem probable that the tube feet would react to ultraviolet radiation.

Discussion

Little is known of which pigments are responsible for photoreception in echinoderms, nor of how they function (Yoshida 1966). However, it is likely that the purple colour of all the light-sensitive tube feet in *Protenaster australis* is significant. Serial sections of the terminal disc of the adapical tube feet reveal dense clusters of cells in the periphery of the disc in areas that are the darkest purple. These cells appear dark when stained with haematoxylin (Figure 3), indicating either the presence of a large nucleus, and/or a strongly acidophyllic cytoplasm (J. Keesing, pers. comm.). It is quite probable that these cells are the light-sensitive cells and that similar cells occur concentrated in the purple bands in all three types of light-sensitive tube feet in *P. australis*.

A number of spatangoid echinoids, such as *Meoma ventricosa*, are known to emerge at night, but remain buried during the day. Chesher (1969) considered that this nocturnal emergence occurred in response to a reduction in oxygen content of the sediment. *Protenaster*, like many other spatangoids, possesses a peripetalous fasciole. When burrowed the upper half of the test of *Protenaster*, enclosing the petals, is enveloped by mucus secreted by the fasciole. An opening is created by a tuft of long spines around the apical system, to allow surface water to pass over the respiratory tracts in the petals. It seems unlikely that any changes in the oxygen content of the sediment would adversely affect the respiration rate of the echinoid. This rate is likely to be entirely controlled by the oxygen content of the sea water at the sediment/water interface.

Although it is not known whether *Protenaster* emerges at night, its morphological similarity to *Meoma*, the absence of funnel-building mucus-secreting tube feet in ambulacrum III, and its shallow mode of burrowing suggests that night emergence is quite likely. Furthermore, specimens kept in an aquarium in low levels of ambient illumination, below the lower threshold, fed quite actively on the sediment surface without attempting to burrow, whereas when they were originally collected and were placed on the sediment surface during daylight,

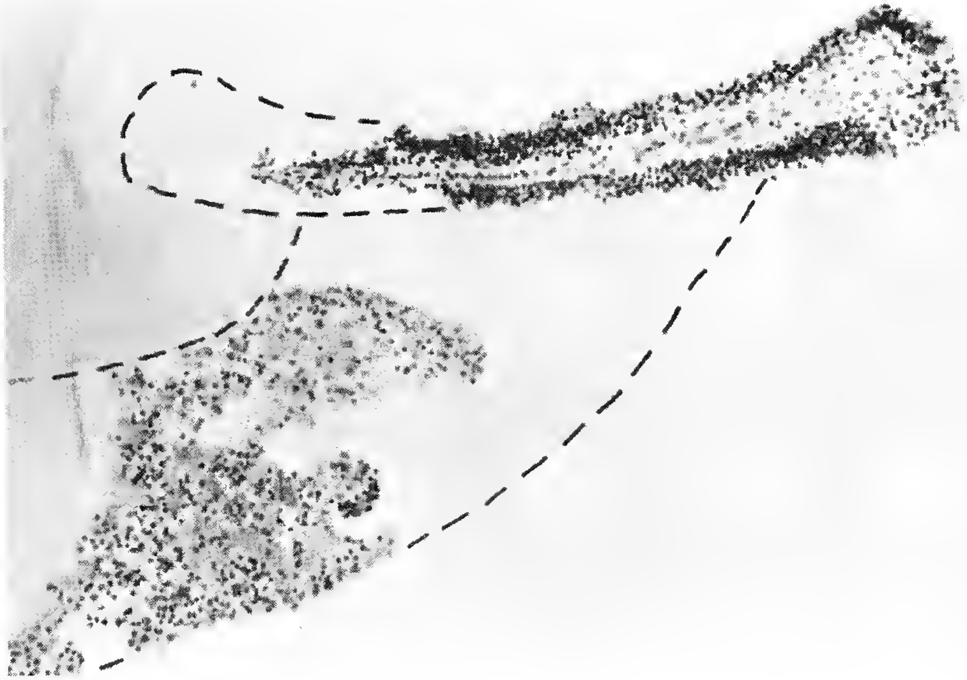

Figure 3 Longitudinal serial section through incomplete terminal pad and stem of a light-sensitive tube foot from the aboral part of ambulacrum III. The cells around the periphery of the pad, which have stained darkly with haematoxylin, are thought to be the light-sensitive cells; x 238.

they burrowed completely (C. Bryce, pers. comm.). Night emergence in *Protenaster* would be possible, given the absence of stimulation of the adoral light-sensitive tube feet at night. However, whether or not there is any particular advantage to be gained from surface feeding at night is questionable. Although there may be fewer vertebrate predators at night, the number of invertebrate predators is likely to be higher than during the day. The presence of light-sensitive tube feet in an adapical position may serve a more important function during the day in warning the echinoid of any exposure of the test to daylight. This is particularly important to *Protenaster* which is known to occur intertidally and to inhabit very shallow rock pools on a limestone reef.

In order to assess the significance of the two levels of light response in the tube feet of ambulacrum III, the ambient light intensity was measured at noon in Perth on a sunny day when the shade temperature was 32°C. With the sun nearly overhead, the light intensity was about 175,000 lux, while in the open shade the reading was about 8500 lux. The similarity of the ambient light levels in shade and sunlight to the levels of response of the tube feet in ambulacrum III argues for an important role for the tube feet in ensuring complete burial during the day. Some regular echinoids have a 'covering reaction' in response to high levels of illumination (Mortensen 1943a, b). This is accomplished by covering the test with opaque objects. Two of the four species of regular echinoids which have been shown to possess light-sensitive tube feet, *Lytechinus variegatus* and *Psammechinus miliaris*, are known to exhibit a 'covering reaction'. However, these, and other regular echinoids, also show dermal photosensitivity. *Protenaster* is unlikely to have such dermal sensitivity as the surface of the test is entirely covered by small spines, unlike regular echinoids where the larger, more sparsely distributed spines do not effectively shade the test. On detecting light above the lower threshold level, *Protenaster australis* may be considered to undergo a similar 'covering reaction', to regular echinoids, by burrowing into the sediment and completely covering the test with sand grains. In *Protenaster australis*, therefore, the adapical light-sensitive tube feet play an important role in controlling burrowing activity and ensuring complete coverage of the test by sediment during daylight.

The phyllodal and ambital tube feet play dual roles in being light-sensitive as well as carrying out other functions. The adaptive significance of light sensitivity in adoral tube feet in an echinoid which burrows in the sediment can only be fully realised if the animal was exhumed from the sediment during daylight and overturned. Immediate retraction of the tube feet would prevent damage by harmful ultra-violet rays in the very shallow water inhabited by the echinoid. Although relatively sheltered in their sand pocket on the reef platform, the environment is periodically one of very high hydrodynamic activity during high tides. In such a situation *Protenaster australis* is liable to be periodically dislodged during storms. Indeed, specimens of *Protenaster australis* in collections have mainly been derived from tests picked up on beaches inland from reefs, attesting to exhumation during the periods of high hydrodynamic activity.

In contrast to the phyllodal and ambital tube feet the adapical tube feet appear to carry out only a single function, that of light detection. Although the tube feet in ambulacrum III of some spatangoids are mucus-generating and used to establish a funnel to the surface when buried (Nichols 1959c; Chesher 1963), there is no evidence that the adapical tube feet in *Protenaster australis* also have a mucus-secretory function. Indeed, their very simple structure, consisting of a swollen light-sensitive terminal pad, contrasts with the structure of the more elaborate mucus-secreting tube feet found in ambulacrum III in spatangoids such as *Echinocardium*, *Moira*, *Aeropsis*, *Brissopsis*, and *Hemiaster*. In these genera the terminal disc extends from having a scalloped margin, as in *Brissopsis* and *Hemiaster*, to possessing a central pad margined by a ring of papillae, as in *Echinocardium* (Smith 1980).

The simple light-sensitive tube feet of *Protenaster australis* compare more closely with the simple tube feet of regular echinoids (Smith 1978). The corresponding pore pairs, unipores separated by a prominent interporal partition, likewise resemble those of many regular echinoids. Smith (1980) has suggested that tube feet, such as those in ambulacrum III in *Protenaster australis*, may, in spatangoids, be paedomorphic. However, rather than considering them to be of paedomorphic derivation, it may be more appropriate to consider them as being the only tube feet on the test not to have developed 'beyond' the simple ancestral structure of regular echinoid tube feet. In this regard the respiratory, ambital and phyllodal tube feet in spatangoids might more suitably be regarded as being peramorphic (*sensu* Alberch *et al* 1979) in origin.

Whether or not other spatangoids respond to light is not yet known, although night-emergent spatangoids such as *Meoma,* may well possess this facility. Light-sensitive tube feet in *Protenaster* are unlikely to have been phylogenetically recently derived not only because of their similar structure to those of regular echinoids, but also because of the long fossil history of *Protenaster.* Although *Protenaster* had until recently only been known from the living species *P. australis,* three fossil species are now known, which range back to the Late Eocene in Australia and New Zealand (McNamara in press). These fossil species possess adapical pore pairs in ambulacrum III which are structurally identical to those of *P. australis.* It is more likely that burrowing spatangoids such as *Echinocardium, Moira, Brissopsis* and *Schizaster,* which have adapical tube feet in ambulacrum III adapted to funnel construction, have probably lost the ability to respond to light and spend their entire lives within the sediment. However, confirmation is still required that these genera do not have light-sensitive tube feet. Hopefully, in the light of this paper, examination will be made in the future of the response of tube feet to light in spatangoids other than *Protenaster.*

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