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CONTENTS **PAGES**

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BY GAVIN J. PRIDEAUX

Summary

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PRIDEAUX, G. J. 2000. *Simosthenurus newtonae* sp. nov., a widespread sthenurine kangaroo (Diprotodontia: Macropodidae) from the Pleistocene of southern and eastern Australia. *Records of the South Australian Museum* **33**(1): 1–15.

Simosthenurus newtonae sp. nov. is described from the Pleistocene of southern and eastern Australia. Its cranium is similar in size to *Simosthenurus occidentalis*, but is less brachycephalic and has a narrower, more elongate rostrum with a less inflated frontal region. The moderately high-crowned molars are distinctive among the species of *Simosthenurus*, because they bear very few to no fine enamel crenulations, and primary crests that bear strong contacts with cusp apices. In these respects, the molars resemble *Sthenurus andersoni* and *Hadronomas puckridgi*.

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Sthenurines were a diverse group of robust browsing kangaroos common throughout southern and eastern Australia in the Pleistocene. *Simosthenurus newtonae* sp. nov. represents the seventh new sthenurine described since 1992. Although uncommon in most assemblages, it is one of the more widely distributed sthenurines, occurring in 21 localities (Fig. 1). The description of this new species forms the subject of this paper. A review of the phylogenetic relationships, chronology, zoogeography and evolution of the sthenurine kangaroos is currently in preparation.

Materials And Methods

Specimens referable to *Simosthenurus newtonae* sp. nov. are housed in the vertebrate palaeontological collections of the following institutions: Australian Museum, Sydney (AM); South Australian Museum, Adelaide (SAM); Field Museum of Natural History, Chicago (FMNH); Flinders University of South Australia, Adelaide (FU); Museum of Victoria, Melbourne (NMV); Queensland Museum, Brisbane (QM); Queen Victoria Museum, Launceston (QVM); Western Australian Museum, Perth (WAM). Serial designation of the cheek dentition follows Flower (1867), Wilson and Hill (1897) and Luckett (1993), except that the third adult premolars are now recognised as the only second generation cheek teeth in marsupials (Cifelli *et al.* 1996; Luckett and Woolley 1996). Dental nomenclature follows Tedford and Woodburne (1987), Ride (1993) or is standard. Mensuration follows Tedford (1966) and Wells and Murray (1979). All measurements are in millimetres.

Systematics

Order DIPROTODONTIA Owen 1866

Superfamily MACROPODOIDEA Gray 1821

Family MACROPODIDAE Gray 1821

Subfamily STHENURINAE (Glauert 1926)

Genus *Simosthenurus* Tedford 1966

Simosthenurus newtonae sp. nov.
Sthenurus oreas DeVis (in part), 1895: 97.
Sthenurus atlas Glauert, 1912: 64.
Sthenurus andersoni Bartholomai (in part), 1963: 58, fig. 3.
Sthenurus sp. Lundelius, 1963: 77, fig. 2.
Sthenurus sp. cf. *S. gilli* Merrilees, 1965: 29–30.
Sthenurus andersoni Tedford (in part), 1966: 25.
Sthenurus sp. II Marcus, 1976: 71, 74, fig. 27c–d.
Simosthenurus sp. II Pledge, 1980: 137, table 3.
Sthenurus sp. Williams, 1980: 107, site 30.
Sthenurus sp. cf. *S. atlas* Williams, 1980: 107, site 37.

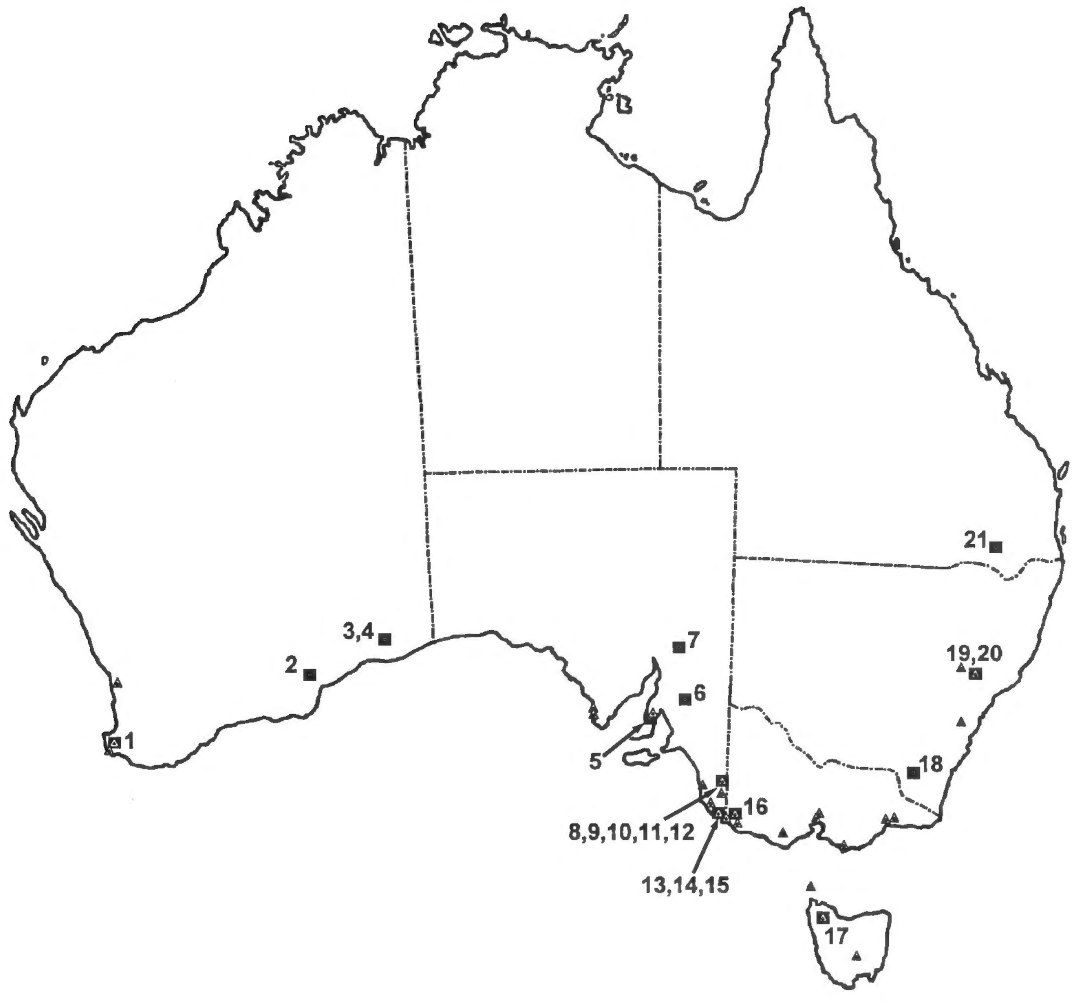

FIGURE 1. Localities yielding remains of *Simosthenurus newtonae* sp. nov. (black squares): 1, Tight Entrance Cave; 2, Balladonia; 3, Madura Cave; 4, Lindsay Hall Cave; 5, Curramulka Quarry; 6, Black Rock Gravel Pit; 7, Baldina Creek; 8, Comaum Forest Cave; 9, Haystall Cave; 10, Henschke's Fossil Cave; 11, SOS Cave; 12, Victoria Fossil Cave; 13, Goulden's Hole; 14, Green Waterhole Cave (*Type locality*); 15, Kilsby's Hole; 16, McEachern's Cave; 17, Scotchtown Cave; 18, Teapot Creek; 19, Kandos; 20, Wellington Caves; 21, Darling Downs. Triangles denote localities yielding *Simosthenurus occidentalis.*

Sthenurus sp. Lundelius & Turnbull, 1989: 2, 4, fig. 1a.
Simosthenurus sp. nov. Prideaux & Wells, 1994: 227.
Sthenurus 'P17250' McNamara, 1994: 111, 115.
Sthenurus 'P17250' Prideaux & Wells, 1997: 191, 194.

Holotype

SAM P17249–P17250, partial adult cranium, and fused left and right dentaries (Figs. 2, 3).

Type Locality

Green Waterhole Cave, a submerged cave near Tantanoola, southeastern South Australia. Faunal composition suggests a late Pleistocene age (Pledge 1980; Newton 1988).

Paratypes

FU 0227, near complete adult cranium; FU 0252, juvenile cranium devoid of occipital region; SAM P20255–P16632–P16633, partial adult cranium, incomplete left and right dentaries; SAM

P28969, near complete, but crushed adult cranium; FU 0179, right dentary. All paratypes are from the Fossil Chamber in Victoria Fossil Cave, Naracoorte, southeastern South Australia. This locality is considered to be late Pleistocene, but is probably older than 212 000 years (Wells *et al.* 1984; Ayliffe *et al.* 1998).

Referred Specimens

Victoria Fossil Cave, Naracoorte, SA: FU 0205, partial right juvenile dentary; FU 0226, right M_3; FU 0259, partial left juvenile dentary; FU 0293, partial left adult dentary; FU 0887, partial left juvenile maxilla; FU 1084, partial left juvenile maxilla; SAM P16550, partial juvenile cranium; SAM P20243, partial left adult maxilla; SAM P27631, left I_1, M_{1-2}; SAM P28149, partial left adult dentary; SAM P28478, right P_3; SAM P28479, right M_1, M_3; SAM P28518, left I_1; SAM P28671, left juvenile dentary; SAM P28996, left juvenile dentary; SAM P32533, left M_3; SAM P32541, left I_1; SAM P32542, left I_1, M_3; SAM P32545, partial right juvenile dentary.

Haystall Cave, Naracoorte, SA: SAM P36624, right dP_2.

Henschke's Fossil Cave, Naracoorte, SA: SAM P17837, partial left juvenile maxilla, right dP^2, right M^1; SAM P18554, right M^1 metaloph; SAM P34807, right P^3; SAM P34808, left P^3; SAM P34809, right P^3; SAM P34810, right P_3; SAM P34811, left P^3; SAM P38788, dP_{2-3}, P_3, M_{1-2}, right P_3, M_1; SAM P38789, left and right M^4; SAM P38790, left P_3; SAM P38791, right M_4; SAM P38792, left P^3; and SAM P unregistered, several loose teeth.

SOS Cave, Naracoorte, SA: SAM P33476, partial right adult maxilla.

Comaum Forest Cave, near Penola, SA: SAM P31967, fused left and right premaxillae and maxillae.

Goulden's Hole, near Mount Schank, SA: SAM P36620, right P^3; SAM P36621, left P_3; SAM

FIGURE 2. Right lateral view of partial cranium and dentaries of *Simosthenurus newtonae* sp. nov. holotype, SAM P17249 / P17250. Small gradations on scale bar are millimetres.

P36622, left M^1; SAM P38780, left M^4; SAM P38781, left M_4.

Kilsby's Hole, Mount Gambier, SA: SAM P38782, left P^3, SAM P38783, right lower molar, SAM P38784, left upper molar, SAM P38785, right dP_2.

Black Rock Gravel Pit, near Orroroo, SA: SAM P23166, left and right adult dentaries.

Baldina Creek, Burra, SA: SAM P21035, partial juvenile dentary.

Curramulka Quarry, Yorke Peninsula, SA: SAM P38786, right P^3, SAM P38787, right P_3.

McEachern's Cave, near Nelson, VIC: SAM P17319, partial right adult dentary; NMV P198434–P198438–P198440, left and right adult maxillae; NMV P198435–P198436, left and right adult maxilla; NMV P198439, partial left adult dentary; NMV P198449, partial left adult maxilla; NMV P198450, right P^3 in maxilla fragment.

Teapot Creek, Monaro Region, NSW: AM F unregistered, partial right adult dentary.

Wellington Caves, NSW: AM F18872, left P^3.

Kandos, NSW: AM F73721, partial left adult dentary.

Darling Downs, southeastern QLD: QM F2978, partial right adult maxilla.

Scotchtown Cave, near Smithton, TAS: QVM:1992:GFV:232, right M_3; QVM:1992: GFV:238, right M^3; QVM:1992:GFV:242, right M^1.

Madura Cave, Madura, WA: FMNH PM4356, right P_3.

Lindsay Hall Cave, near Madura, WA: WAM 92.12.3, right M^1; WAM 92.12.10, right M^3; WAM 00.1.1, partial right juvenile maxilla.

Balladonia Soak, near Balladonia, WA: WAM 63.11.2–63.11.3, right adult dentary.

Tight Entrance Cave, southwestern WA: WAM

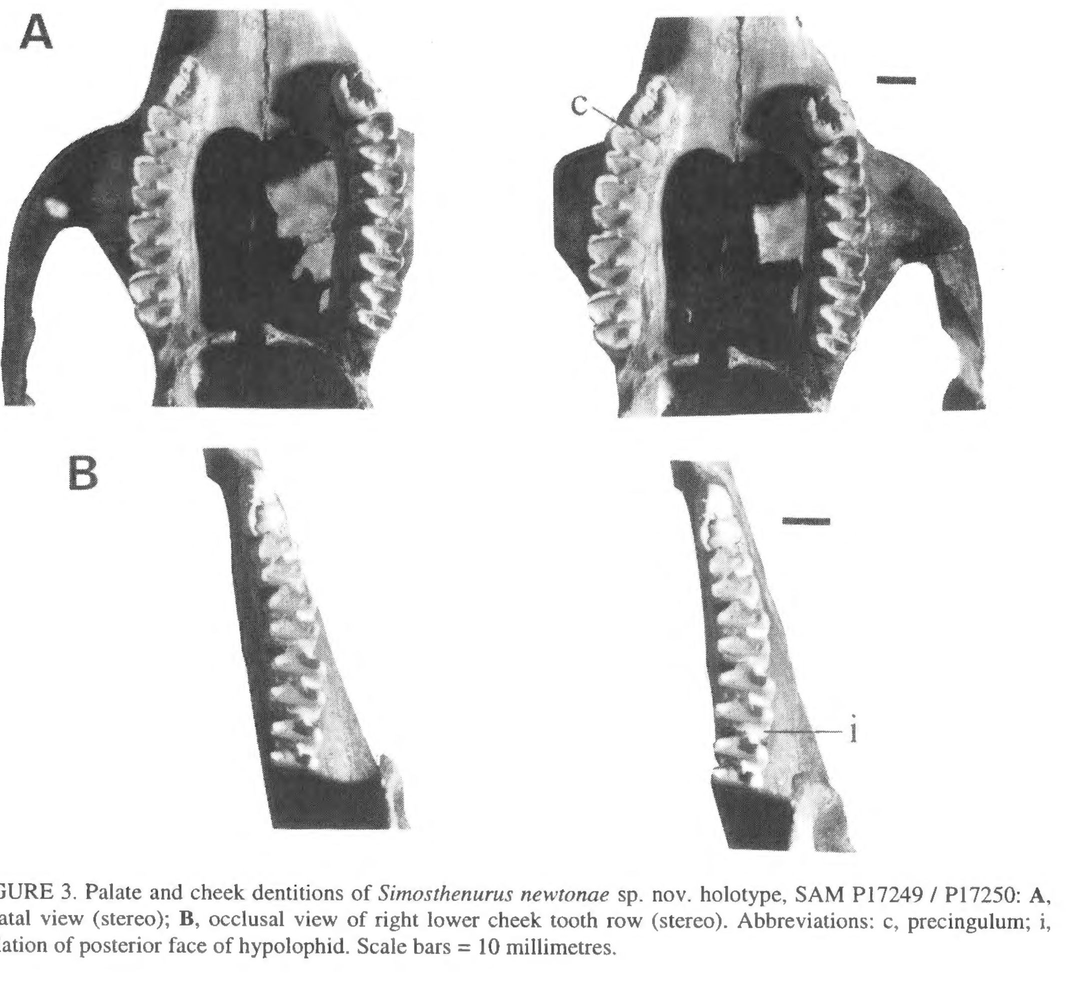

FIGURE 3. Palate and cheek dentitions of *Simosthenurus newtonae* sp. nov. holotype, SAM P17249 / P17250: **A**, palatal view (stereo); **B**, occlusal view of right lower cheek tooth row (stereo). Abbreviations: c, precingulum; i, inflation of posterior face of hypolophid. Scale bars = 10 millimetres.

97.5.312–97.5.314–97.5.314–99.11.142, left adult dentary.

Species Diagnosis

Cranium similar in size to *Simosthenurus brownei* Merrilees 1967 and *Si. occidentalis* Glauert 1910, but less brachycephalic, with narrower, more elongate rostrum, longer diastema and less inflated frontal region. Masseteric process short, narrowing distally and twisted posteriorly. P^3 short for width, crown inflated anterobuccally and thus only slightly wider posteriorly than anteriorly. Upper and lower molars relatively high-crowned with very few to no fine enamel crenulations. Crests on molars very well-developed, generally maintaining strong contact with cusp apices. Precingulum abruptly terminated at position of preprotocrista. Pterygoid fossa narrow and dorsoventrally deep. Lower molars bear pronounced anterior turn of lophid ends and strongly inflated posterior face of hypolophid.

Etymology

The new species is named after Cate A. Newton who studied the fossil fauna of Green Waterhole Cave and first recognised the morphological uniqueness of the holotype.

Description

Cranium (Figs 2–5; Table 1).

Premaxilla rather slender in lateral view, but flaring dorsally for extended contact with nasal. Incisor-bearing portion of premaxilla rather shallow and elongate (Fig. 5). Diastema moderately elongate, maxilla-premaxilla suture elongate and zigzagged. Cranial diastema deflected anteroventrally relative to cheek tooth row. Incisive foramina long with anterior border opposite or just posterior to posterior extremity of I^3 alveolus. Rostrum narrow, deep and elongate. Anteorbital/buccinator fossae on maxilla very shallow, resulting in reduced mesial curvature of diastema ridge, and rather flat-sided maxilla anteroventral to centre of orbit. Nasals long, broad posteriorly, narrowing anteriorly. One to three infraorbital foramina anterior to ventral border of orbit. Masseteric process short, moderately wide, flaring slightly towards distal end, twisted posteriorly under anterior portion of jugal (Figs 2–5). Process consists primarily of maxilla with only modest jugal contribution. Frontal region rather elongate in dorsal view, only moderately inflated laterally (Fig. 4A). Palatine vacuities extend anteriorly to opposite M^1 precingulum. Postpalatine bars form a thin bridge across palate opposite or posterior to M^4 metaloph (Fig. 3A).

Basicranial plane markedly elevated above palatal plane. Cranial pterygoid fossa wide and deep. Basioccipital slightly flexed posterodorsally relative to basisphenoid, and bears well-developed medial keel. Zygomatic arch deep, with a very wide ectoglenoid process at posterior extremity of jugal. Postglenoid process and glenoid fossa very large. Temporal crests not fully convergent on sagittal suture and only moderately developed. Occipital region broad, but not especially deep, and oriented at 90° relative to dorsal surface of neurocranium. Vertical medial occipital crest

TABLE 1. Mean dimensions of the adult cranium and dentary of *Simosthenurus newtonae* sp. nov. compared with the dimensions of the holotype (SAM P17249–P17250) and mean dimensions of *Simosthenurus occidentalis* and *Sthenurus andersoni*. Standard deviation is given in parentheses; sample size in brackets.

Dimension	***Simosthenurus newtonae***	***Holo-type***	***Simosthenurus occidentalis***	***Sthenurus andersoni***
Condylobasal Length	216 (3.0) [n=3]	–	198 (4.9) [n=4]	221 (8.5) [n=2]
Diastema Length	40.3 (1.04) [n=4]	–	31.8 (1.42) [n=4]	47.2 (4.38) [n=2]
% Diastema Length: Palatal Length	30.5 (0.85) [n=3]	–	25.2 (0.01) [n=4]	36.0 (2.83) [n=2]
Palatal Length	132 (1.2) [n=3]	–	126 (4.1) [n=4]	132 (2.1) [n=2]
Palatal Width between M^1 Protolophs	37.2 (2.27) [n=5]	39.0	35.0 (0.46) [n=3]	38.8 (0.92) [n=2]
Palatal Width between M^4 Protolophs	39.2 (4.05) [n=3]	43.1	41.2 (0.53) [n=3]	42.1 (0.14) [n=2]
Max. Width across Zygomatic Arches	132 (5.6) [n=4]	136	143 (1.53) [n=3]	114 (2.1) [n=2]
Maximum Width across Frontals	77.5 (3.05) [n=4]	82.0	91.8 (3.22) [n=4]	63.4 (1.98) [n=2]
Width across Paroccipital Processes	76.3 (5.12) [n=4]	82.0	67.7 (2.67) [n=3]	62.7 (3.25) [n=2]
Dentary Depth	34.8 (3.35) [n=5]	39.3	37.6 (1.70) [n=13]	28.4 (1.82) [n=10]
Dentary Width	20.5 (1.20) [n=5]	20.6	23.4 (2.03) [n=13]	17.2 (2.04) [n=10]
Dentary Depth / Width	1.70 (0.13) [n=5]	1.91	1.62 (0.14) [n=13]	1.65 (0.13) [n=10]

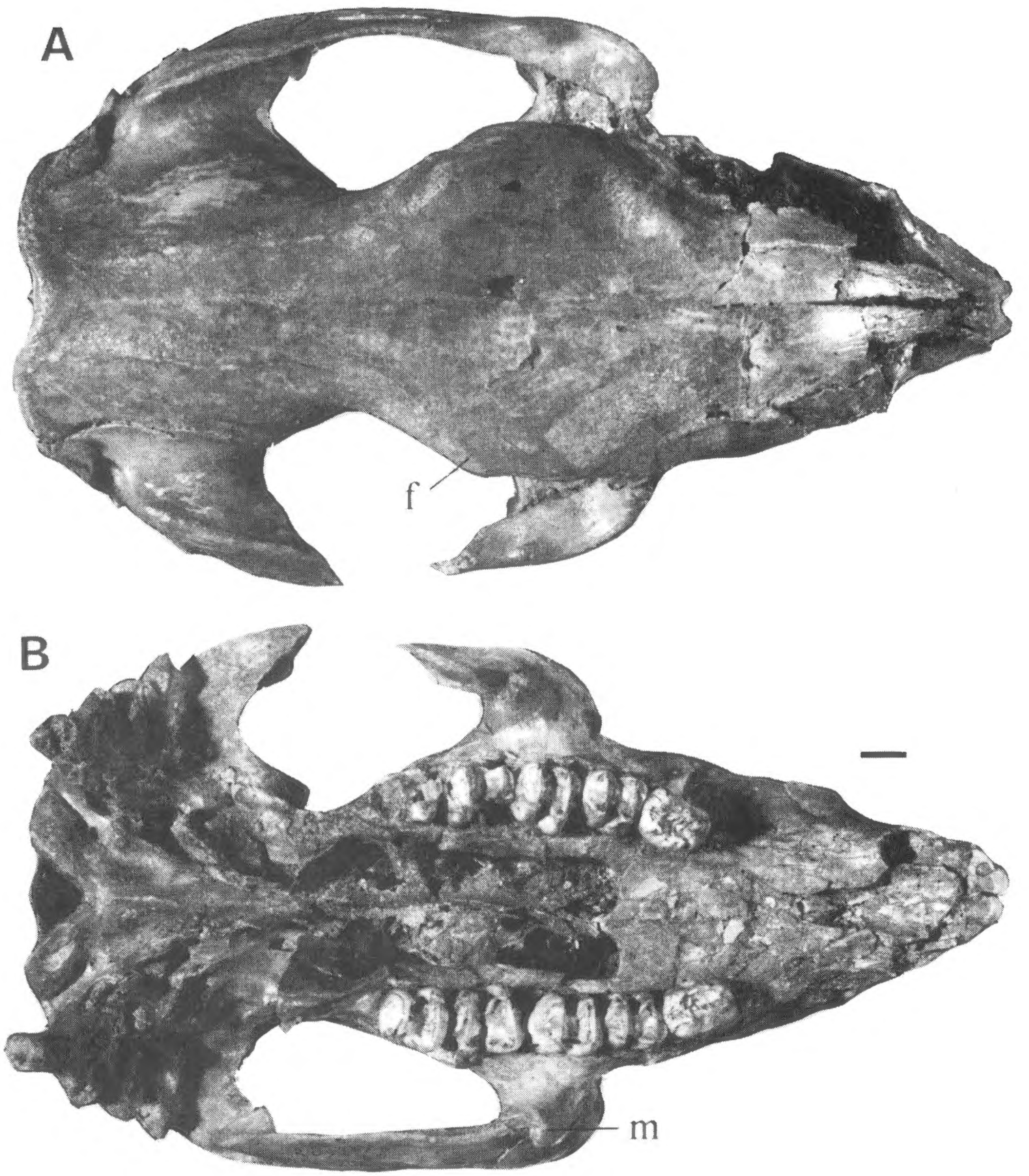

FIGURE 4. Cranium of *Simosthenurus newtonae* sp. nov. paratype, SAM P28969: **A**, dorsal view; **B**, palatal view. Abbreviations: f, frontal; m, masseteric process. Scale bar = 10 millimetres.

slight to well-developed, and leads ventrally to wide foramen magnum bordered by moderately large occipital condyles. Paroccipital processes deflected posteroventrally. Nuchal crests strongly-developed and extended posteriorly (Fig. 4A).

Upper Dentition (Figs 2–5; Table 2).

I^1 quite low in crown height and rather rounded in cross-section (Figs 4–5). Vertical occlusal facet faces posteriorly. Strongly curved anterior surface of crown extends forward well beyond anterior extremity of premaxilla. I^2 round in cross-section, one-third size of I^1. I^3 unknown, but alveolus suggests elongate crown.

Second upper deciduous premolar (dP^2) reminiscent of P^3 in general morphology, but

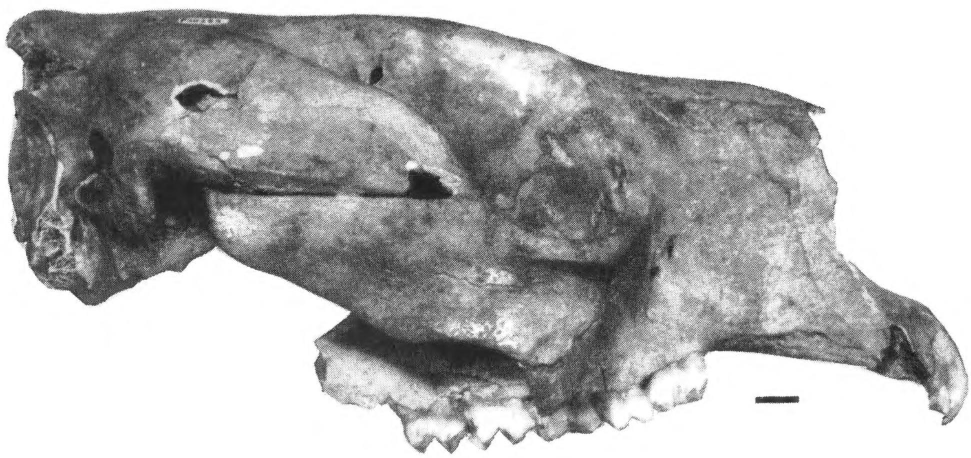

FIGURE 5. Right lateral view of partial cranium of *Simosthenurus newtonae* sp. nov. paratype, SAM P20255. Scale bar = 10 millimetres.

much shorter relative to width. Outline of tooth very rounded, especially on lingual side. Main crest straight and aligned with antero-posterior plane of tooth, lingual crest very curved and much lower in height than main crest. Anterior basin absent. Posterior basin well-developed, half size of longitudinal basin and separated by marked transverse ridge. Third upper deciduous premolar (dP^3) completely molariform, narrower across protoloph than metaloph and smaller than molars. Small precingulum restricted to buccal two-thirds of protoloph face, terminating at position of preprotocrista. Unworn crest of protoloph very convex anteriorly with very thick, united postparacrista and premetacrista. Remaining aspects very similar to molars, except for fine postlink and crest centred on posterior face of protoloph. P^3 usually short for width, only slightly wider posteriorly than anteriorly (Figs 3–5; Table 2). Outline rounded, with anterobuccal aspect strongly inflated and lingual side convex. Posterobuccal accessory cusp absent, poorly differentiated or slight, very occasionally with small, poorly differentiated cuspule anterior to it. Lingual crest lower and usually more curved than main crest. Anterior basin small and not well differentiated. Longitudinal basin short, of modest width and depth, and occupied by fine to coarse transverse ridgelets. Posterior basin well-developed, and separated from longitudinal basin by strong transverse ridge formed by two strong ridgelets united at tooth midline, or by buccally curved end of lingual crest.

Upper cheek tooth row moderately curved buccally, with P^3 turned in slightly relative to molars (Figs 3A, 4B). Upper molars sized $M^1<M^2<M^3>M^4$ (Figs 2–5; Table 2). Metaloph narrower relative to protoloph on M^4 than on M^{1-3}. Lophs moderately high-crowned, with unworn crests slightly convex anteriorly. Loph faces bear few very fine or no enamel crenulations. Preparacrista strongly developed, and maintains strong, direct contact with paracone apex. Precingulum smoothly confluent with preparacrista and terminates at tiny remnant of preprotocrista, after extending across two-thirds of anterior face of protoloph (Fig. 3A). Prominent postprotocrista ascends posterobuccally into interloph valley, but only extends onto base of metaloph face as very short, fine crest. Well-developed postparacrista and moderately developed premetacrista curve in lingually, their union forming a distinct notch. Posterior face of metaloph dominated by well-developed postmetaconulecrista, which curves buccally across approximately three-quarters of posterior face of metaloph to meet similarly-developed postmetacrista. Tiny cuspule positioned at union of postmetaconulecrista and postmetacrista most prominent on M^3, and probably represents stylar cusp E. Posterior face of metaloph markedly inflated above postmetaconulecrista, especially more buccally.

Dentary (Figs 2, 3, 6; Table 1).

Ramus deep for width, especially posteriorly due to large digastric eminence (Figs 2,6), which curves in mesially along ventral border. Digastric

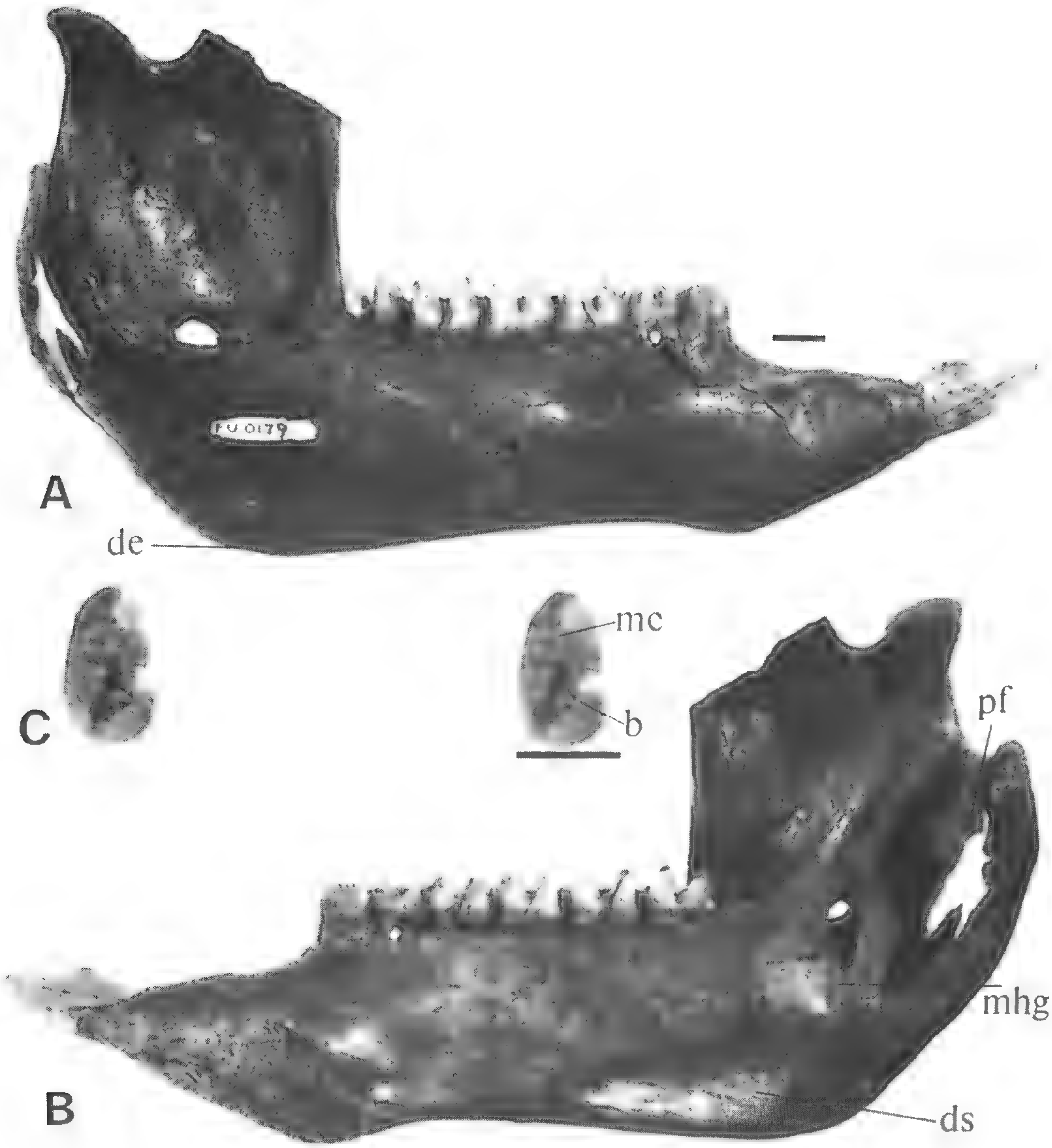

FIGURE 6. Right dentary of *Simosthenurus newtonae* sp. nov. paratype, FU 0179: **A**, lateral view; **B**, mesial view; **C**, occlusal view of excavated right P_3 (stereo). Abbreviations: b, buccal crest; de, digastric eminence; ds, digastric sulcus; mc, main crest; mhg, mylohyoid groove; pf, pterygoid fossa. Scale bars = 10 millimetres.

sulcus large and extends anteriorly to beneath M_2 hypolophid or M_3 protolophid (Fig. 6B). Dentary decreases in depth anteriorly, with diastema somewhat procumbent relative to cheek tooth row (Figs 2, 6). Symphysis rather slender and procumbent, with dorsal border parallel with alveolar margin of cheek tooth row. Posterior portion of symphysis underlies small genial pit, and only extends to beneath posterior root of P_3. Median dorsal groove deep and narrow. Anterior mental foramen located just anteroventral of buccinator sulcus. Buccinator sulcus shallow anteriorly, but gradually deepens posteriorly, terminating beneath M_1 hypolophid. Posterior mental foramen mid-depth on ramus beneath M_2 hypolophid.

Ascending ramus rather short in lateral profile with anterior root located adjacent to M_4 hypolophid (Figs 2, 6). Anterior root forms buccal aspect of wide, deep postalveolar fossa. Masseteric foramen large and elliptical, leading into deep vertical masseteric canal which does not extend into body of ramus. Inferior mandibular foramen usually fairly large, with dorsal border at level of alveolar margin of cheek tooth row. Pterygoid fossa high and narrow, bearing pronounced upward projection of angular process (Figs 2, 6). Adjacent to ventral border of inferior mandibular foramen and at anterior extremity of pterygoid fossa, two sharp processes overhang mylohyoid groove; a posteroventrally-oriented process (cf. lingula in humans) and an anterodorsally-oriented process extending from anterior end of mesial border of pterygoid fossa (Fig. 6B). Mandibular condyle large.

Lower Dentition (Figs 2, 6; Table 2).

I_1 large, robust, elongate (Figs 2, 6). Occlusal surface slightly higher than, but oriented close to parallel with diastema. Level of I_1 occlusal surface well below level of cheek tooth occlusal surfaces. Second lower deciduous premolar (dP_2) similar in overall morphology to P_3, but shorter relative to width. Main crest runs obliquely across tooth from posterolingual corner to central position anteriorly. Short buccal crest trends buccally from posterior extremity of main crest, then curves anteriorly to run parallel to posterior part of main crest for short distance. Third lower deciduous premolar (dP_3) completely molariform, with protolophid slightly narrower than hypolophid and tapered markedly toward relatively narrow unworn crest. Small paraconid positioned at anterior extreme of trigonid, lingual to end of paracristid. Premetacristid runs posteriorly from paraconid, terminating midway up metaconid anterior face. Thick ?parametacristid descends smoothly from metaconid apex terminating in middle of trigonid basin. ?Preprotostylocristid runs anteriorly from topographic protoconid apex to point where paracristid turns lingually. Cristid obliqua strongly-developed, continuous with buccal extremity of hypolophid, meets protolophid slightly posterolingual and ventral to protoconid. Preentoconid low, curves from entoconid apex into interlophid valley to near midline of tooth. Very slight posterobuccally-accentuated inflation present on posterior face of hypolophid. Lophid faces lack enamel crenulations.

P_3 small and moderately short relative to molars, usually similar to or slightly shorter than M_3 in length (Figs 2, 3, 6; Table 2). Posterobuccal aspect of tooth inflated and bearing short, thick buccal crest separated from posterior end of main crest by very shallow, narrow median valley in holotype (Fig. 3B). In paratypes and referred specimens, inflation of posterobuccal corner less marked; buccal crest usually slightly longer and bears a thin, crescentic buccal crest separated from main crest by small and shallow median valley (Fig. 6C). Cuspules of main crest poorly differentiated posteriorly, but three usually distinguishable anteriorly. Very few to no ridgelets traverse median valley.

Lower cheek tooth row shows slight to moderate buccal curvature, with main crest of P_3 oriented slightly anterobuccally relative to molars (Fig. 3B). Moderately high-crowned lower molars sized $M_1 < M_2 < M_3 > M_4$ (Figs 2, 3, 6, Table 2). Lophid faces often lack enamel crenulations, but a few very fine crenulations may be present on anterior faces. Anterior turn of lophid ends very pronounced (Fig. 3B). Paracristid and cristid obliqua well-developed, with former maintaining contact with topographic protoconid apex, and latter contacting or very close to hypoconid apex (Fig. 3B). Precingulid/trigonid shelf narrow and moderately short. Transverse (anterior) portion of paracristid broadly U-shaped in unworn teeth, curving out to anterior extremity of tooth, above precingulid, then posteriorly, usually uniting with fine, low premetacristid. ?Parametacristid either slight or absent. Cristid obliqua on minimally worn teeth divided into anterior and posterior components, although moderate wear produces one continuous crest. Lower posterior component curves smoothly anteriorly from hypoconid apex and terminates on buccal side of anterior component, located closer to midline of tooth and oriented less obliquely. Anterior component of cristid obliqua extremely slight anterior to interlophid valley, fining and terminating midway up posterior protolophid face. Preentoconid low and very slight. Shelf-like postcingulid absent, but buccal two-thirds of posterior aspect strongly inflated more ventrally, and overlapped by trigonid of succeeding molar (Figs 3B, 6A).

Intraspecific Variation

Cranium

There is very little variation in the general size and morphology of known adult crania that cannot be ascribed to differential preservation. The only noteworthy variation is a slight difference in

TABLE 2. Cheek tooth dimensions of *Simosthenurus newtonae* sp. nov., showing mean and standard deviation (in parentheses), dimensions of the holotype (SAM P17249–P17250), and the Wellington Caves and Kandos specimens (AM F18872, AM F73721).

Tooth	Length	Anterior Width	Posterior Width	Anterior Height	Posterior Height	Sample Size
UPPER DENTITION						
dP^2	10.3 (0.91)	7.7 (0.51)	9.6 (0.97)	7.1 (0.47)	7.8 (0.81)	3
dP^3	11.5 (0.20)	9.8 (0.66)	10.9 (0.42)	6.2 (0.85)	7.0 (1.15)	3
P^3						
Mean	16.6 (0.72)	10.5 (0.82)	12.3 (0.52)	10.4 (0.61)	10.1 (0.86)	15
Holotype	16.9	10.6	12.9	11.0	10.8	
AM F18872	18.3	10.0	13.4	10.3	9.8	
M^1						
Mean	13.2 (0.32)	12.9 (0.50)	12.6 (0.38)	7.7 (0.79)	7.9 (0.71)	11
Holotype	13.2	13.1	12.8	8.3	8.0	
M^2						
Mean	14.5 (0.60)	13.9 (0.82)	13.0 (0.65)	8.2 (0.71)	8.4 (0.71)	12
Holotype	14.7	13.7	13.0	9.0	8.7	
M^3						
Mean	15.0 (0.59)	13.7 (0.53)	12.9 (0.63)	7.9 (0.48)	7.9 (0.37)	12
Holotype	15.0	13.8	13.3	8.3	8.3	
M^4						
Mean	14.1 (0.67)	12.9 (0.36)	11.1 (0.42)	6.6 (0.55)	6.2 (0.52)	8
Holotype	14.8	13.0	11.5	7.5	6.6	
LOWER DENTITION						
dP_2	9.5 (0.68)	6.1 (0.49)	8.1 (0.31)	7.9 (0.95)	7.1 (0.83)	6
dP_3	10.4 (0.21)	8.3 (0.57)	8.8 (0.53)	7.1 (0.89)	7.2 (0.90)	6
P_3						
Mean	15.3 (0.74)	7.6 (0.43)	9.3 (0.33)	10.1 (0.79)	9.4 (1.16)	16
Holotype	15.3	7.7	9.7	10.0	10.1	
AM F73721	17.5	8.4	9.9	–	–	
M_1						
Mean	13.1 (0.67)	10.2 (0.37)	10.5 (0.35)	9.2 (0.98)	9.7 (1.47)	14
Holotype	13.1	10.1	10.7	9.1	9.7	
AM F73721	14.3	11.4	11.7	–	–	
M_2						
Mean	15.2 (0.61)	11.3 (0.38)	11.6 (0.34)	10.0 (1.38)	10.4 (1.35)	12
Holotype	15.7	11.5	11.7	9.2	9.6	
AM F73721	16.0	12.5	13.0	–	–	
M_3						
Mean	16.3 (0.45)	12.1 (0.29)	12.3 (0.42)	9.5 (1.43)	9.4 (1.25)	11
Holotype	16.6	12.1	12.4	9.5	9.5	
AM F73721	17.3	13.5	13.8	10.1	11.7	
M_4						
Mean	14.6 (0.79)	11.5 (0.28)	10.4 (0.44)	8.4 (0.74)	7.3 (0.55)	8
Holotype	15.8	11.3	10.7	8.6	7.3	
AM F73721	17.0	13.0	12.2	10.8	10.3	

zygomatic arch depth, with SAM P28969 shallower than SAM P17249, SAM P20255 and FU 0227.

The juvenile cranium, FU 0252 (dP^{2-3}, M^{1-2} erupted), clearly differs from the adult crania in proportion. The rostrum is relatively longer, the ventral orbital border of the jugal is less laterally expanded, the frontal region is less inflated, the temporal crests are less convergent upon one another, and the width across the zygomatic arches is comparatively less.

Upper Dentition

No appreciable variation is visible in I^1 size or morphology between the four specimens preserving that tooth. These same specimens also preserve I^2 but, in contrast to I^1, I^2 of SAM P20255 is slightly smaller in cross-sectional area than in the other specimens, even taking into consideration its greater degree of wear. Minimal size or morphological variation has been observed for dP^2, aside from the presence of an incipient posterobuccal accessory cusp in SAM P16550, a low, slight posterobuccal cingulum in FU 1084, and the complete absence of any such feature in FU 0252 and FU 1084. The longitudinal basin is slightly larger in FU 0252 than FU 1084, but SAM P16550 is too worn to determine. No notable size or morphological variation is visible in dP^3. Upper molar variation is also very limited, with the slightest fine enamel crenulations visible on the unworn molars of some specimens.

Marked variation exists in both size and morphology between the P^3 of the holotype, paratypes and referred specimens. Size differences are present in absolute length and width, crown height, and width relative to length, although no geographically-correlated size variation is evident. Morphological variation is displayed in: a) degree of posterobuccal accessory cusp development (ranging from clearly defined with small anterior cuspule, to poorly differentiated, to completely absent); b) degree of curvature of lingual crest and degree to which both crests are divided into cuspules; c) nature of coarse ridgelet separating posterior and longitudinal basins (composed of continuation of lingual crest or two transverse ridgelets); d) general inflation or roundness of tooth outline.

It is worth singling out a rather large, unworn P^3 from Wellington Caves (AM F18872) for special consideration, because it is much wider posteriorly than anteriorly. Although this conflicts with one of the defining characteristics of *Si. newtonae*, all other features of the tooth fit within the recognised *Si. newtonae* morphospace. These features include the inflation of the anterobuccal corner, shape of the lingual crest relative to the main crest, presence of one small cuspule immediately anterior to a poorly differentiated posterobuccal accessory cusp, and buccal curvature of the posterior end of the lingual crest, such that it partially separates the longitudinal and posterior basins. For these reasons, and because *Si. newtonae* is known from a dentary with rather large molars from nearby Kandos (AM F73721), I am confident that the Wellington Caves specimen is *Si. newtonae*.

Dentary

Few morphological differences are visible between the adult dentary specimens apart from slight variation in the posterior extent of the symphysis (beneath the anterior and posterior roots of P_3), and degree of development of the digastric eminence and sulcus. As a consequence of the latter variable feature, dentary depth varies slightly between specimens (e.g., compare the holotype dimensions with mean dimensions in Table 2). Variation is also present in the size of the inferior mandibular foramen and development of the processes overhanging the mylohyoid groove. Relatively, the holotype has the deepest dentary, largest inferior mandibular foramen and largest mylohyoid associated processes. Disregarding overall size differences, comparison of adult and juvenile specimens reveals a trend with age for increased dentary depth relative to width, and development of the digastric eminence and sulcus.

Lower Dentition.

No significant variation is visible in I_1 and dP_3. Similarly, there is little variation in dP_2, with only a slight difference between specimens in overall size, relative length of the buccal crest, and the variable presence of a ridgelet linking the anterior end of the buccal crest to the second cuspule of the main crest. While some size variation is evident in P_3, the considerable degree of morphological variation mirrors that observed in the P^3. Variation is displayed in: a) general tooth outline (rounded and gently narrowing anteriorly with minimal differentiation into anterior and posterior portions, posterobuccal corner inflated with much of buccal side and lingual side near parallel); b) shape of main crest (longitudinally straight, slightly sinusoidal); c) degree to which main crest cuspules are differentiated; d) relative length and shape of buccal crest (very short and thick, short and crescentic); e) low, fine ridgelet connecting buccal crest to second cuspule of main crest (absent, present); f) width of median valley and degree of development of contained ridgelets. The P_3 also varies slightly in the degree to which its longitudinal axis is deflected anterobuccally relative to the curvature of the molar row. The minimal variation noted for the upper molars also holds for lower molars.

The Kandos dentary (AM F73721) varies slightly from typical *Si. newtonae*, because its P_3 and molars are around 10% larger. This is noteworthy in view of the marked similarity in dental size between specimens of *Si. newtonae* from across its wide range, which includes western and Tasmanian representatives. Although the dentition is considerably worn, no morphological differences are evident between the cheek teeth of AM F73721 and similarly worn specimens of *Si. newtonae*. While it is important to note that the digastric region, ascending ramus and anterior portion of the ramus are missing in AM F73721, the dentary of this specimen only differs from other individuals of *Si. newtonae* by possessing a buccinator sulcus that is slightly deeper anteriorly. In view of the marked variation in size observed within other *Simosthenurus* species (Prideaux 1999), I have very little hesitation in referring this specimen to *Si. newtonae*.

Comparison with other taxa

Cranium.

The cranium of *Simosthenurus newtonae* is more dolichocephalic than that of any other *Simosthenurus* species. In relative skull length it is intermediate between the other *Simosthenurus* species and *Sthenurus* Owen 1874, resembling *Hadronomas puckridgi* Woodburne 1967 in this regard. Among the species of *Simosthenurus*, the *Si. newtonae* cranium is most similar to *Si. occidentalis*, but it differs by having a more elongate rostrum and diastema, and a less posterodorsally-flexed basioccipital region. Despite the otherwise similar occipital and basicranial proportions of the two species, the direct effect of these differences is that the portion of the cranium posterior to the end of the maxilla is longer in *Si. newtonae* than it is in *Si. occidentalis*. Inflation of the frontal region and development of the supraorbital crests are less pronounced in *Si. newtonae* than in *Si. occidentalis* and *Si. brownei*, but greater than in *Si. gilli* Merrilees 1965 and *Si. baileyi* Prideaux and Wells 1998. The masseteric process is shorter and much narrower than *Si. occidentalis*, and is closest in morphology to *Si. maddocki* Wells and Murray 1979, but more twisted posteriorly. Moderate development of the temporal crests is similar to *Si. baileyi*. The shallow anteorbital/buccinator fossae and reduced mesial curvature of the diastema border resemble *Si. baileyi* as well as *Si. gilli*, but both of these species have much shorter rostra.

Upper Dentition.

The general shape of the *Si. newtonae* I^1 is typical of most *Simosthenurus* species, but the tooth is quite low-crowned, akin to that of *Si. brownei*. Although the elongate I^3 alveolus probably indicates a relatively elongate crown, I have observed no I^3 which may be confidently ascribed to *Si. newtonae*. The dP^2 of *Si. newtonae* is smaller than in southeastern *Si. brownei* and *Si. occidentalis*, but larger than in *Si. maddocki* and *Sthenurus andersoni* Marcus 1962. Morphologically, the tooth recalls *Si. brownei* and *Si. baileyi*, but it is less inflated posteriorly. Although quite variable in form, the P^3 of most *Si. newtonae* individuals is quite dissimilar to the other *Simosthenurus* species. This is especially so because, relative to its length, the tooth is usually quite wide anteriorly as well as posteriorly. The manner in which the posterior end of the lingual crest curves buccally to partially or wholly separate the longitudinal and posterior basins is only seen elsewhere in *S. andersoni*, as well as a P^3 fragment from the early Pliocene Bow Local Fauna of central eastern New South Wales (see Fig. 1A in Flannery and Archer 1984). Marked inflation of the anterobuccal corner of P^3 is only seen in rare individuals of other *Simosthenurus* species.

The upper molariform teeth of *Si. newtonae* are unique among *Simosthenurus*, and cannot readily be confused with any other species. They are similar to *Si. baileyi* in size, but are easily distinguished by being higher-crowned, lacking any noteworthy enamel crenulations, and having the primary crests strongly connected to cusp apices. The smaller *Si. gilli* and *Si. maddocki* upper molars bear some resemblance to *Si. newtonae* in this latter feature, as well as the curved nature of the postparacrista and premetacrista. However, all crests on the molars of *Si. maddocki* are more weakly developed than in *Si. newtonae*, while the majority of crests are more weakly developed in *Si. gilli*. The postprotocrista, which is divided into two components, and the better developed upper molar midline crest of *Si. gilli* are the two exceptions. *Si. maddocki* may also be distinguished from *Si. newtonae* by the many very fine enamel crenulations that coat its loph surfaces. Overall, the molars of *Si. newtonae* are most similar to *S. andersoni*, but they differ by having the preparacrista much more strongly connected to the paracone apex, a stronger premetacrista, a stronger postmetaconulecrista and no continuation of the precingulum beyond the preprotocrista. Although a precingulum that does not extend lingually beyond the preprotocrista on the upper molars is unique to *Si. newtonae*, this condition is observed on the dP^3 of *S. andersoni*.

Dentary.

Si. newtonae is most similar in dentary size and morphology to *Si. brownei*, but the digastric eminence of the latter species is usually larger, as is the gradient of decreasing dentary depth anteriorly. In addition, the masseteric fossa is longer in *Si. brownei*, and the anterior root of the ascending ramus lies opposite the M_3–M_4 boundary or M_4 protolophid. In contrast, the anterior root in *Si. newtonae* leaves the ramus adjacent or just posterior to the M_4 hypolophid. The slightly procumbent diastema of *Si. newtonae* is not observed in any other *Simosthenurus* species, but is observed in *Sthenurus*, in *S. tindalei* Tedford 1966 and *S. stirlingi* Wells and Tedford 1995. The slender symphysis of *Si. newtonae* is most similar in size and form to that of *Si. brownei*, but it does not extend under the genial pit to the same degree, and its dorsal surface is nearly horizontal rather than anterodorsally-oriented. The narrow and deep median dorsal groove present in *Si. newtonae* is also characteristic of *Si. maddocki*.

Viewed posteriorly, the pterygoid fossa of *Si. newtonae* is narrower than in any other *Simosthenurus* species. Marked development of the processes overhanging the mylohyoid groove is similar to *Si. oreas* De Vis 1895, but the groove in the latter species is deeper and narrower.

Lower Dentition.

In size and morphology, the I_1 of *Si. newtonae* is intermediate in morphology between *Si. occidentalis* and *S. andersoni*. In this sense, the tooth resembles the I_1 of *Si. pales* De Vis 1895, but is much smaller. Size and general outline of the dP_2 is similar to *Si. occidentalis*, but the tooth is relatively narrower anteriorly. The shortness of the buccal crest is similar to that observed in *Si. maddocki*, but the dP_2 of this species is narrower and the main crest cuspules are more distinct. As with the P^3, the anterior width of P_3 is not markedly exceeded by the posterior width of the tooth. Overall, *Si. newtonae* is particular similar to *Si. brachyselenis* Prideaux and Wells 1997 in size and general morphology, but differs by being longer relative to the molars and having a slightly longer buccal crest. While the P_3 of the *Si. newtonae* holotype is similar in outline to that of *Si. brachyselenis*, other specimens of *Si. newtonae* often narrow more gradually anteriorly. Compared with '*Simosthenurus*' *cegsai* Pledge 1992, the *Si. newtonae* P_3 is more inflated posterobuccally, the median valley is usually wider, and the buccal crest is longer.

Although the protolophid base of the *Si. newtonae* dP_3 is narrower than the hypolophid base, the unworn crest of the protolophid is much narrower, similar to that of *Si. pales*. *Si. newtonae* appears to retain a paraconid lingual to the paracristid in the anterolingual corner of the dP_3 trigonid. A similar cusp is often observed on the dP_3 of other sthenurines, such as *Si. gilli*, *S. atlas* (Owen 1838) and *Hadronomas puckridgi*. Aside primarily from the stronger connection between the cristid obliqua and hypoconid apex, morphology of the *Si. newtonae* dP_3 is very similar to the succeeding molars. Among the species of *Simosthenurus*, the morphology of the *Si. newtonae* lower molars is quite unique. In some respects, their form more closely resembles species of *Sthenurus*, most especially *S. andersoni*. Similarities include the paucity of enamel crenulations on the lophid faces, the proximity of the paracristid and cristid obliqua to the buccal cusp apices, and the anterior turn of the lophid ends. Within *Simosthenurus*, the *Si. newtonae* lower molars most resemble *Si. gilli* in crown height and paucity of enamel crenulations, but are easily distinguished by their larger size, markedly inflated posterior face of the hypolophid, more curved transverse portion of the paracristid, and thicker, more buccally situated paracristid and cristid obliqua. A curved transverse portion of the paracristid is also observed in *Si. euryskaphus* Prideaux and Wells 1997 and many specimens of *Si. occidentalis*, but the paracristid and cristid obliqua of these two species are shifted more lingually, the lophid faces bear distinct fine enamel crenulations, and the lophid ends are less markedly turned anteriorly. In this latter feature and in the marked posterior inflation of the hypolophid, *Si. newtonae* is easily distinguished from all other *Simosthenurus* species.

Geographic Distribution

Simosthenurus newtonae is one of the most widely distributed Pleistocene sthenurine species. Overall, its distribution pattern most closely resembles that of *Si. occidentalis* (Fig. 1). Both species occur in late Pleistocene cave deposits in southwestern Australia (Merrilees 1979; Gully 1997), and were probably distributed across the southern periphery of the continent during periods when woodland or forest was more extensive. However, of these two species, only *Si. newtonae* has so far been recorded from Balladonia (= *Sthenurus atlas* in Glauert 1912) and the Nullarbor Plain (Lundelius, 1963; Lundelius and Turnbull 1989; Prideaux 1994; Aplin *et al.* 1995). Conversely, only *Si. occidentalis* is known from the Eyre Peninsula.

Remains of *Si. newtonae* and *Si. occidentalis* are commonly encountered in the cave faunas of southeastern South Australia (eg., Pledge, 1980; Wells *et al.*, 1984), although the latter species is much better known in Victoria. Together, they represent the only sthenurines known from late Pleistocene cave deposits in Tasmania, where *Si. occidentalis* is again by far the more abundant (Murray and Goede 1977; Goede and Murray 1979). While *Si. newtonae* is also known from southeastern Queensland (= *S. andersoni* in Bartholomai 1963), its only other occurrence north of the Monaro region in southeastern New South Wales is in the form of a large-toothed variant in the Kandos and Wellington Caves deposits.

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TWO NEW SPECIES OF *ANTIPORUS* SHARP FROM WESTERN AUSTRALIA (COLEOPTERA: DYTISCIDAE).

BY C.H.S. WATTS AND A.PINDER

Summary

WATTS, C.H.S. AND PINDER, A. (2000). Two new species of *Antiporus* Sharp, *A. pennifoldae* and *A. mcraeae*, are described from the south –west of Western Australia. Both species appear to be restricted to an area threatened by rising salinity.

TWO NEW SPECIES OF *ANTIPORUS* SHARP FROM WESTERN AUSTRALIA (COLEOPTERA: DYTISCIDAE)

C. H. S. WATTS AND A. PINDER

WATTS, C. H. S. and PINDER, A. 2000. Two new species of *Antiporus* from Western Australia (Coleoptera: Dytiscidae). *Records of the South Australian Museum* 33(1): 17–19.

Two new species of *Antiporus* Sharp, *A. pennifoldae* and *A. mcraeae*, are described from the south-west of Western Australia. Both species appear to be restricted to an area threatened by rising salinity.

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Two new species of *Antiporus* Sharp have recently been identified from the south-west of Western Australia. These were among material collected in a biological survey of wetlands in the wheatbelt and adjacent areas by the Department of Conservation and Land Management (CALM). The survey is part of the department's response to problems (particularly salinity and waterlogging) associated with rising groundwater in the region as a consequence of extensive clearing of native vegetation.

Members of the genus *Antiporus* are common in still, or relatively still, water in southern Australia. One species, *A. femoralis* Boheman, is particularly common in the South-West. In a recent revision of the genus, Watts (1997) described two additional species from the region, both seemingly rare with one, *A. pembertoni* Watts, known only from one specimen from near Pemberton and the other, *A. hollingsworthi* Watts, from 15 specimens. Since then further collecting has provided two additional localities for *A. hollingsworthi* (30 km N Perth, coll. Watts, 15 km S Northcliffe, coll. Pederzani; both in the South Australian Museum), but none for *A. pembertoni*.

We herein report on and describe two additional species which, like the above, are known from very few specimens. The species were not collected during a recent more intensive survey of wetland invertebrates in the Lake Muir/Poorginup region by A. Storey (personal communication) and will probably prove to have a restricted distribution. The area in which they were found is generally threatened by rising salinity.

We describe the two species here to enable them to be included in the ongoing investigation of this important wetland region.

Systematics

Antiporus mcraeae sp. nov.

Type

Holotype: male; 'Melaleuca Swamp, Kodjinup Nature Reserve, 50 km ESE Manjimup, 34°23'45"S 116°39'01"E, W.A. Coll. A. Pinder and J. McRae (CALM), 2/10/98' Registration number WAM 26607, Western Australian Museum.

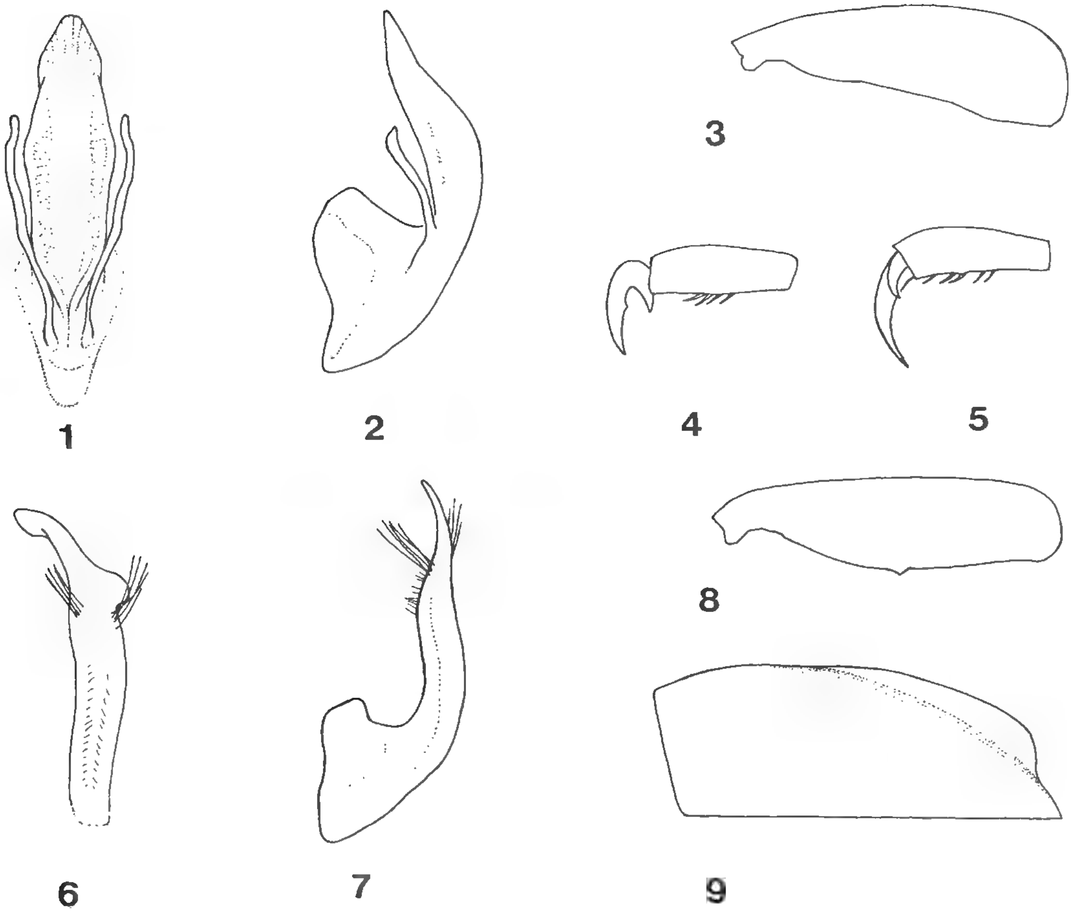
Description (number examined, 1) (Figs 1–4)

Habitus. Length 4.4 mm. Elongate-oval, dark red-brown, sides of pronotum broadly paler, appendages lighter particularly towards extremities.

Dorsal surface. Punctures rather small, regular, those on head smaller than eye facet; row of larger punctures adjacent to suture on elytron; a few small depressions along base of elytron; microreticulation fine, moderately impressed. Pronotal margin narrowly beaded, elytron weakly so.

Ventral surface. Evenly rugose-punctate, punctures somewhat larger than on elytron. Prothoracic process relatively narrow, parallel sided, ridged, tip blunt. Metacoxal lines parallel in posterior quarter, broadening to about 2 times their narrowest width anteriorly, area between them and forward onto mesosternum depressed.

Male. Protarsi moderately expanded, basal segment round, third very deeply bilobed; single claw relatively stout, bent at right angles, with small basal tooth (Fig. 4). Mesotibia quite strongly indented on inner margin near apex; mesotarsi only slightly less expanded than protarsi.



FIGURES 1–9. **1**, Dorsal view of median lobe of aedeagus of *A. mcraeae*; **2**, ditto lateral view; **3**, ventral view of male metafemur of *A. mcraeae*; **4**, lateral view of proclaw and apical tarsal segment of male *A. mcraeae*; **5**, ditto *A. pennifoldae*; **6**, dorsal view of median lobe of aedeagus of *A. pennifoldae*; **7**, ditto lateral view; **8**, ventral view of metafemur of male *A. pennifoldae*; **9**, dorsal view of elytron of female *A. pennifoldae*.

Mesofemur considerably broader towards apex, anterior margin near apex straight (Fig. 3). Median lobe of aedeagus relatively simple but with a thin lateral piece arising from near base on both sides (Fig. 1).

Female. Unknown.

Remarks

The size, colour pattern, relatively broad metacoxal lines with the area between them depressed, male mesotibia indented and male metatibia expanded, place this species in the *A. femoralis* complex. Among these, the relatively weak punctation, the shape of the male metatibia and aedeagus ally it with *A. pembertoni* Watts. It differs from this species in the shape of the male proclaw which is a little more robust and the central lobe of the aedeagus having an additional piece on each side. In this unusual character it resembles *A. pembertoni* which has a single additional piece arising dorsally.

In the key given to Australian *Antiporus* in Watts (1997) it (male) will run to the *A. femoralis* complex. Further identification within this complex depends on characters of the male proclaw, metafemur and aedeagus (see Figs 1–4, and those in Watts (1997).

Habitat

The single specimen was collected from a small, slightly acidic (pH 6.0), fresh (1.0 ppt) Melaleuca swamp.

Etymology

Named after Jane McRae, the co-collector of the specimen.

Distribution

Known only from the type locality in the wheatbelt region of south-western Western Australia.

Antiporus pennifoldae sp. nov.

Types

Holotype: male; 'Lake Poorginup, 62 km SE Manjimup, 34°32'56"S 116°44'29"E, W.A. Coll. A. Pinder and J. McRae (CALM), 2/10/98'. Registration number WAM 26606. Western Australian Museum.

Paratype: female; same data as holotype, South Australian Museum.

Description (number examined, 2) (Figs 5–9)

Habitus. Length 3.3–3.4mm. Elongate-oval, reddish-brown, appendages lighter.

Dorsal surface. Punctures dense, moderately sized; those on head weaker and sparser, a little smaller than eye facet; a row of large punctures on elytron adjacent to suture, forming weak groove. Pronotum and elytron with narrow but well marked lateral beading. Microreticulation fine, moderately impressed.

Ventral surface. Punctures similar to those on elytron. Pronotal process blunt, sides weakly bowed, moderately ridged. Postcoxal lines parallel in apical quarter, weakly diverging to about 1.4 times narrowest width, area between them flat, not depressed.

Male. Protarsi moderately expanded, proclaw relatively stout, evenly curved with moderate lateral rather than ventral basal spine (Fig. 5). Mesotibia normal, mesotarsi similar to protarsi except that third segment a bit shorter and two claws present. Metafemur a little stouter than in female with a small triangular spine on hind margin in middle (Fig. 8). Apical third of elytron weakly flanged. Median lobe of aedeagus with asymmetric tip in dorsal view, distal portion setiferous (Fig. 6).

Female. Protarsi weakly expanded, two claws. Mesotarsi moderately expanded, more so than protarsi. Metatibia simple. Elytron very widely flanged, beginning in middle and expanding until same width as rest of elytron near apex, then ending abruptly, a short apical portion of elytron not flanged (Fig. 9).

Remarks

A relatively small reddish species, the female of which is instantly recognisable by the strongly flanged elytra. In the male only a rather indistinct narrow flange is present. The distinctly asymmetric and setiferous median lobe of the aedeagus are characters not shared by any other *Antiporus*.

In the key to Australian *Antiporus* in Watts (1997) the females of *A. pennifoldae* can be taken out at the start by the presence of strongly flanged elytra. The males will run to couplet 15, where they can be distinguished from both alternatives by the presence of a small triangular spine on the hind edge in the middle of the otherwise simple metafemur.

The average size, relatively uniform reddish-brown colour and essentially simple metafemora suggest that the species does not belong in the *A. femoralis* complex. It appears to be a rather isolated species.

Habitat

Recorded only from a fresh (0.2 ppt), sedge-filled peat swamp surrounded by Melaleuca shrubs.

Distribution

Known only from the type locality.

Etymology

Named after Melitta Pennifold who was the first to recognise the specific distinction of the specimens.

Acknowledgments

We thank Mr R. Gutteridge for the preparation of the figures, Ms J. McRae for help in the field and Ms M. Pennifold for help in the laboratory.

Reference

WATTS, C. H. S. 1997. Four new species of *Antiporus* Sharp (Coleoptera: Dytiscidae) from Australia, with notes on *A. femoralis* (Boh.) and *A. interrogationis* (Clark). *Records of the South Australian Museum* **30** (1): 35–42.

WHY FLUTES ON BOOMERANGS AND THROWING STICKS?

BY R.C. NELSON

Summary

NELSON, R.C. (2000). At first glance it may seem that the longitudinal flutes on the distinctive throwing sticks and hunting boomerangs of Central and Western Australia must diminish their aerodynamic performance. Nothing could be further from the truth. These surface features enhance the performance. Wind tunnel tests show large drag force reductions in the case of throwing sticks and large lift force increases in the case of boomerangs. The fluting alone is responsible for the improved performance. In fact it can be shown that, without the fluting, some boomerangs may not have flown at all.

WHY FLUTES ON BOOMERANGS AND THROWING STICKS?

R. C. NELSON

Nelson, R. C. 2000 Why Flutes on Boomerangs and Throwing Sticks? *Records of the South Australian Museum* **33**(1): 21–27.

At first glance it may seem that the longitudinal flutes on the distinctive throwing sticks and hunting boomerangs of Central and Western Australia must diminish their aerodynamic performance. Nothing could be further from the truth. These surface features enhance the performance. Wind tunnel tests show large drag force reductions in the case of throwing sticks and large lift force increases in the case of boomerangs. The fluting alone is responsible for the improved performance. In fact it can be shown that, without the fluting, some boomerangs may not have flown at all.

Ray C. Nelson, School of Civil Engineering, University College (UNSW), Australian Defence Force Academy. Manuscript received 30 August 1999.

Notation

A_n Projected area onto a plane normal to V.
A_p Projected area onto a plane parallel to V.
C_d Drag coefficient (dimensionless).
C_l Lift coefficient (dimensionless).
D Diameter.
F_d Drag force.
F_l Lift force.
k Roughness height.
R_e Reynold's number (dimensionless)
V Fluid free stream velocity.
ρ Fluid density.
μ Fluid dynamic viscosity.

Introduction

The aerodynamics of boomerangs has received considerable attention, particularly those of returning boomerangs. One of the earliest attempts to explain the reason why boomerangs return was that of Wilkinson (1841: see reprint 1973:250–254). This was a totally inadequate explanation. It disregarded the fact that the vanes of the boomerang were airfoils that created lift, and it overlooked the gyroscopic nature of a rotating boomerang and the consequent effects of the precessional moment created by the lift force differential between the two ends of the boomerang. The first rigorous and complete aerodynamic study of boomerangs was that of Walker (1898). His analyses were not limited to returning boomerangs. He was able to explain why boomerangs which had strongly developed convex curvature on both faces (the more curved surface uppermost when thrown) and which also had a small negative twist, produced the required characteristics of a non-returning boomerang if thrown with rotation in a horizontal plane. Returning boomerangs often have positive twist and are thrown with the rotation in a near vertical plane.

The best known study of boomerang aerodynamics is that of Hess (1968). It deals exclusively with returning boomerangs. The main contribution was a theoretical study of the boomerang flight path with comparisons to photographic records of boomerang flights. In a later work, Hess (1975:545–549) did provide a brief theoretical analysis of some characteristics of the non-returning boomerang. Cotteral and Kamminga (1990:175–180) drew heavily on the work of Hess (1968) and did extend their work to a brief consideration of the non-returning boomerang.

No published work is available that relates specifically to the aerodynamics of throwing sticks used in Aboriginal Australia. However, the discussion of maximum and minimum principal axes by Cotteral and Kamminga (1990:179–180) and the flight stability provided by the bend in a boomerang, applies equally well to the flight stability provided by the bend in a throwing stick. The bend prevents spin about the longitudinal axis, eliminating any undesired flight characteristics that might result from phenomena such as the Magnus effect (Roberson and Crowe 1997:446–447).

In recent times, Western fascination for the returning boomerang has been responsible for hi-tech design innovations used in modern sporting boomerangs but these are not relevant to this study. The above summary does therefore represent the current aerodynamic knowledge applicable to the traditional throwing sticks and boomerangs once used in Aboriginal Australia. What is clear is that while the impact of surface roughness on the performance of these implements has been the subject of some conjecture (e.g. Hess 1975:31, 37), it has never been tested and quantified. Roughness elements can have a profound influence on the characteristics of the boundary layer as air flows over the surface. This in turn determines the pressure distribution around the implement and the size of the wake formed behind the implement. That is, the behaviour of the boundary layer will determine the lift and drag forces on the implement, which in turn directly affect its performance. It is not only a difference between a rough and a smooth surface that is important but the size and type of the roughness is also significant.

On relatively large (dimension parallel to the flow greater than about 1 m if air is the medium), highly streamlined objects, with very gentle surface curvatures, it is necessary to have the surface as smooth as possible to reduce the skin friction drag. However, on relatively small objects (dimension parallel to the flow of less than 100 mm if air is the medium) with relatively tight surface curvatures, significant improvements in the aerodynamic performance can be obtained by the introduction of surface roughness. This results in drag force reduction and lift force increase and is technology used in modern every day life. For example, the dimples on golf balls greatly reduce the drag forces resisting flight, thereby increasing the distance a well hit ball can travel by about 50 percent (Fox and McDonald 1998: 449–451, Young *et al.* 1997: 410–412). Further, the roughness produced by the stitching on a smooth shiny cricket ball, enables a well bowled ball to generate a lift force normal to the flight path and produces what is known as *swing* (Brown and Mehta 1993). This is done by slanting the seam at an angle to the direction of travel so that on one side only does the air pass over the roughness of the stitching to create a turbulent boundary layer.

The reason for these aerodynamic improvements is that the roughness elements initiate transition from a laminar boundary layer to a turbulent boundary layer closer to the leading edge than would occur naturally on a smooth surface. This natural transition would not normally occur within 100 mm of the leading edge of a smooth, streamlined object moving in air at subsonic velocities. If a smooth, streamlined object has a dimension parallel to the flow of less than 100 mm, the boundary layer can only be turbulent if it is initiated by roughness elements. A turbulent boundary layer adheres longer to the surface, into what is an adverse pressure gradient on the rear portion of the object, before the boundary layer separates from the surface. This creates a narrower wake resulting in a smaller drag force. It also reduces the overall pressure force on that surface to below that which would

FIGURE 1. Typical specimens of hunting boomerangs and fluted throwing sticks.

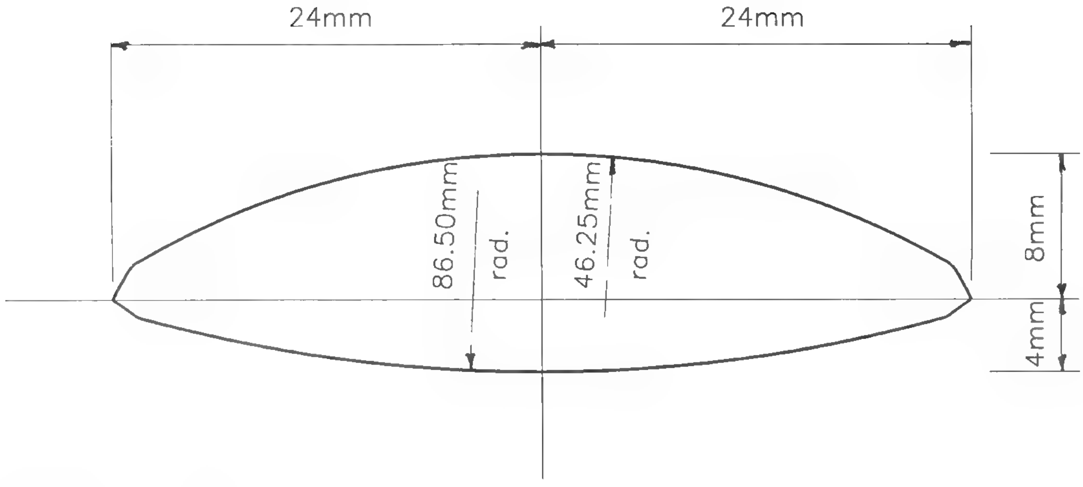


FIGURE 2. Cross-section of smooth foil.

exist if the boundary layer remained laminar. Refer to Street et al. (1996:231–256, 489–418) for further information on boundary layers, drag forces and lift forces.

It is now a small step to suspect that the fluting on the distinctive throwing sticks and hunting boomerangs of Central and Western Australia may have a significant utilitarian purpose. That is, a purpose other than just decorative, ceremonial or sacred in nature, namely aerodynamic. Typical specimens of these artefacts are shown in Fig. 1 while Davidson (1936) has delineated the region where these implements were in use. The specimens shown were collected during the 1920s and belong to the B.L. Hornshaw Collection. Both implements are 640 mm along their axes. The stick has a mass of 521 g (weight 5.11 N), is circular in cross section and has an average diameter of 30 mm. There is longitudinal fluting around the whole circumference. The boomerang has a mass of 314 g (weight 3.08 N) and has a lenticular cross-section that is 48 mm in average width and 12 mm in average maximum thickness. Both faces of the boomerang have a convex curvature, the longitudinal fluting being only on the more highly curved face. In both cases the flutes are about 5 mm wide and 0.2 mm deep. The author perceived that the fluting on the throwing stick was analogous to the dimples on golf balls (drag reduction) while the flutes on the boomerang were analogous to the stitching on a cricket ball (lift enhancement), particularly as the fluting is on one face only.

A series of experiments were designed and undertaken to test these hypotheses. It is these experiments and their results that are the subject of this paper.

Experimental Setup

The experiments were undertaken in a low turbulence wind tunnel with a square test section of side length 457 mm. Wind speeds were measured using a Pitot tube connected to a micromanometer. The maximum wind speed possible in the tunnel was 37 m/s. Models of the implements were supported in the test section by a balance system capable of measuring both the lift and drag forces exerted on the models. The models were 455 mm long with cross sections modelled at full scale. The models were located at mid height in the tunnel with the longitudinal axis normal to the airflow.

The models were manufactured from aluminium on a computer controlled milling machine to dimensions representative of the actual implements shown in Fig. 1. Both smooth and fluted models were manufactured. The selected diameter of the throwing stick was 30.5 mm. The selected cross section of the boomerang (smooth, without flutes) is shown in Fig. 2. The fluted models were made from smooth models using a 15 mm radius router to manufacture grooves 5 mm wide and 0.214mm deep. Photographs of the fluted models are shown in Fig. 3 and Fig. 4.

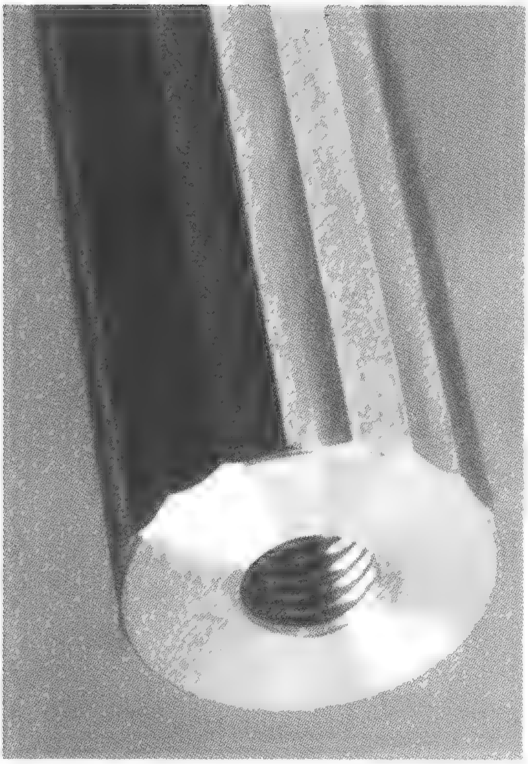


FIGURE 3. Fluted cylinder model.

Throwing Stick Experiments

A throwing stick approximates a circular cylinder for which considerable experimentation has already been undertaken, especially for smooth cylinders. Provided the throwing stick is bent, and therefore prevented from spinning about its longitudinal axis, the only aerodynamic force exerted is that of drag. The magnitude of the drag force is given by Eq. 1 where C_d is the dimensionless drag coefficient and A_n is the projected area onto a plane normal to the airflow.

$$F_d = C_d A_n \frac{\rho V^2}{2} \qquad (1)$$

Clearly, the larger the drag coefficient, the larger the drag force at any given velocity. If the value of C_d is known, the drag force on any diameter cylinder, travelling at any velocity in any fluid can be determined from Eq. 1. However, if C_d is not already known it must be determined experimentally. This can be done using one fluid, one cylinder of given D and series of test runs using a range of V. A_n and ρ would be known, V and F_d would be measured and hence C_d derived from Eq. 1.

The value of C_d is also related to R_e, a dimensionless number defined in Eq. 2 that can also be evaluated from the experimental procedures described above.

$$R_e = \frac{\rho V D}{\mu} \qquad (2)$$

The function of C_d versus R_e for a smooth circular cylinder is given in Fig. 5 after Schlichting (1968). The near horizontal portion of the curve at C_d values of about 1.2 is the region where the boundary layer is laminar. At R_e values between 2×10^5 and 4×10^5 the boundary layer goes through transition from a laminar to a turbulent boundary layer until at R_e values greater than about 4.5×10^5, the boundary layer is completely turbulent and a very significant reduction in C_d is observed. The advantage of having a turbulent boundary layer is obvious. Unfortunately, this could never be achieved on a 30.5 mm diameter, smooth throwing stick, as it would require airflow velocities in excess of about 200 m/s (720 km/hr). The highest value of R_e possible in the wind tunnel was 7×10^4 for a stick diameter of 30.5 mm.

Achenbach (1971) showed how roughness modified the function of C_d versus R_e. The results, shown as the dotted lines in Fig. 5, indicate that the introduction of surface roughness induces transition to a turbulent boundary layer at much lower values of R_e than would occur for a smooth cylinder of the same diameter. The k/D values are the relative roughnesses of the cylinders tested, larger values representing rougher surfaces in relative terms, the roughness type used being sand grains. For example, $k/D = 0.0090$ is equivalent to

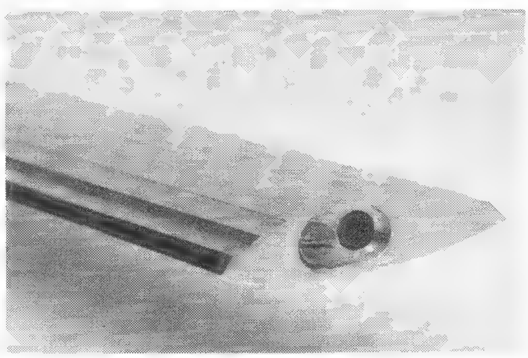


FIGURE 4. Fluted foil model.

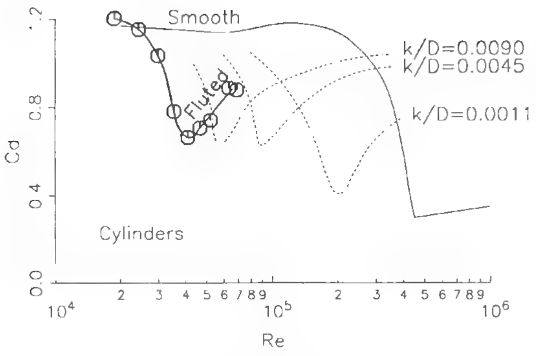


FIGURE 5. *Cd* versus *Re* functions for cylinders.

a sand grain roughness diameter of 0.27 mm on a 30.5 mm diameter cylinder.

The results for the 30.5 mm diameter fluted cylinder are shown in Fig. 5 as the heavy solid line and indicate that the fluted roughness is equivalent to something greater than a sand grain roughness of 0.27 mm. The minimum drag coefficient occurs at R_e equal to $4x10^4$, one order smaller than that for a smooth cylinder.

The dimensionless functions shown in Fig. 5 are universally applicable to any cylinders in any fluid. The impact of flutes on a specific aboriginal throwing stick is best illustrated in Fig. 6 where, for any given velocity less than 37 m/s, the ratio

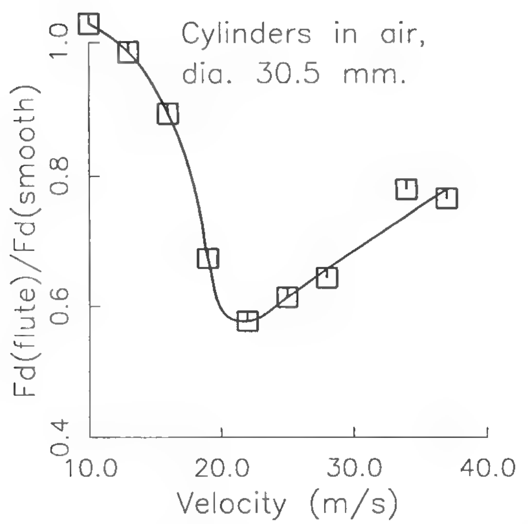


FIGURE 6. Drag force ratios – fluted cylinder/smooth cylinder.

of the drag force on a fluted stick to that on a smooth stick of the same length and diameter, is given. Drag force reductions of up to 40 percent are achieved at velocities of between 20 m/s and 30 m/s with reductions of 20 percent at velocities of 40 m/s. These velocities are achievable by throwing. The velocity of translation of a thrown stick on leaving the hand was probably between 20 m/s and 30 m/s with a superimposed rotation of about 5 rps (revolutions per second) adding a further 10 m/s at the extremity of the forward moving arm. The flutes appear to be the exact type of roughness required to obtain maximum drag force reduction on aboriginal throwing sticks.

Boomerang Experiments

The lenticular cross section of a boomerang, with one surface more highly curved than the other, enables the arms to behave as rudimentary airfoils that will generate a lift force in a direction normal to the direction of the air stream. Drag forces are also generated but, due to the more streamlined nature of the cross section, they are very much smaller than those generated by the throwing stick. They are of secondary importance to the lift forces in the context being considered here. The lift force counteracts the gravity force and prolongs the distance over which the boomerang can be propelled. It is this ability to generate lift that distinguishes a boomerang from a throwing stick.

The magnitude of the lift force is given by Eq. 3, which in form is very similar to the equation

$$F_l = C_l A_p \frac{\rho V^2}{2} \qquad (3)$$

for drag force (Eq. 1) but with different definitions of some terms. C_l is the dimensionless lift coefficient and A_p is the projected area of the airfoil onto a plane parallel to the airstream direction.

Clearly, the larger the lift coefficient the larger the lift force at any given velocity. However, as with the cylinder, if the lift coefficient is unknown it must be determined experimentally. With A_p and ρ known and V and F_l measured, the value of C_l can be derived.

The value of C_l varies with the angle of attack, the angle between the chord of the airfoil and the direction of the airstream. The results for the airfoils tested are given in Fig. 7 and show the lift coefficient to be much larger for the fluted foil

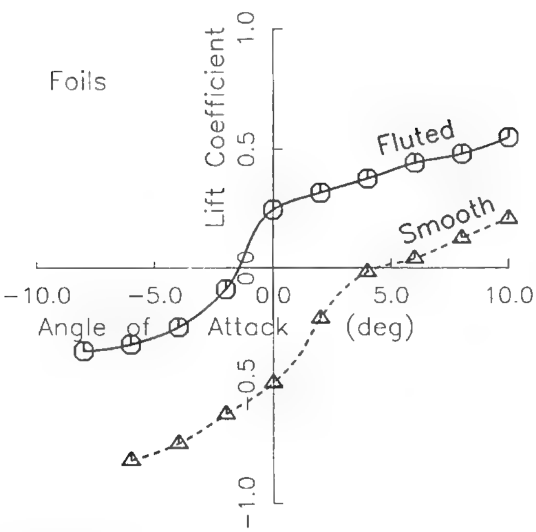


FIGURE 7. Lift coefficient versus angle of attack for foil models.

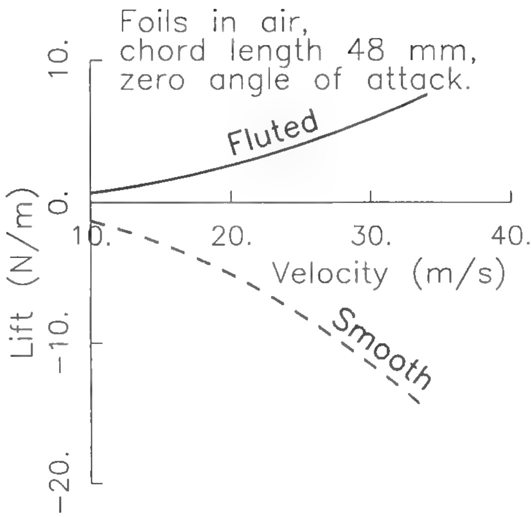


FIGURE 8. Lift forces on foil models.

than for the smooth foil at all angles of attack tested. The smooth foil did not generate positive lift (upward lift) until the angle of attack exceeded about +5 degrees. The angle of attack for most of the length of a hunting boomerang is zero degrees. A small negative twist (negative angle of attack) is sometimes placed on the outer tip to lessen the lift force in that region to reduce the precessional moment that might otherwise cause the boomerang to climb excessively (Walker 1898 and Cotteral and Kamminga 1990:180).

In the absence of flutes, the boomerang modelled would not have flown at all as evidenced by the very significant negative lift coefficient (-0.5) at zero angle of attack. Flow visualisation techniques indicated that on the more gently curved underside, flow separation was delayed until very near the trailing edge, while flow separation occurred early on the rear half of the more highly curved topside. The result was an efficient negative (downward) force on the underside but a lesser, inefficient, positive (upward) force on the topside, the sum total being a negative (downward) lift force.

The flow separation on the topside of the fluted foil was delayed until very near the trailing edge, thereby generating an efficient, positive (upward) force that exceeded the magnitude of the negative (downward) force on the smooth underside, the sum total being a net positive (upward) lift force. The flutes induce a turbulent boundary layer that can adhere longer to the more tightly curved surface, as described in the Introduction. It should be noted that roughness on the underside would have little impact on the lift characteristics. The airflow was able to adhere satisfactorily to the more gently curved, smooth surface without the assistance of roughness. Therefore, the fact that a boomerang may have some roughness on the underside (adze marks for example) is not important.

Fig. 8 shows the overall lift forces generated on the two models, while Fig. 9 shows the increase in lift force generated by the presence of flutes. The values are given in Newtons per metre length

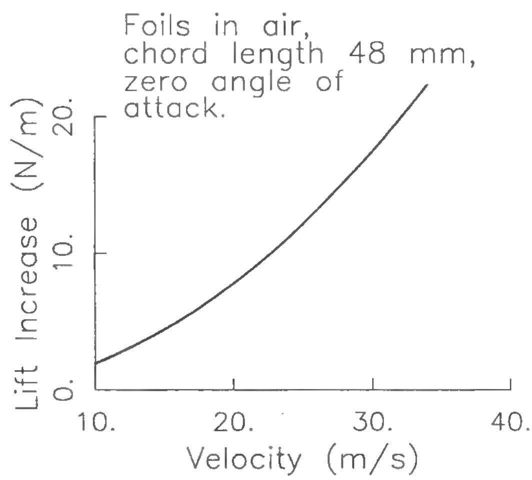


FIGURE 9. Increase in lift force attributable to flutes.

of foil (N/m). A hunting boomerang typically weighs between 4.5 N/m and 5.0 N/m. Therefore, the fluted foil tested has the lift characteristics required of a boomerang launched at a velocity of translation of between 20 m/s and 30 m/s and a rotation of about 5 rps, values thought to be characteristic of those actually used in Aboriginal Australia (refer to section Throwing Stick Experiments).

Comments and Conclusions

The testing of fluted and non-fluted samples of throwing sticks and boomerangs has shown that their aerodynamic performance is notably improved by the fluting. The wind tunnel tests show large drag force reductions for throwing sticks and considerably increased lift forces for boomerangs. The fluting alone is responsible for this improved performance. The fluted boomerang tested appears to have the optimum lift characteristics. Without the fluting it has negative net lift and therefore, becomes less efficient than a throwing stick which has zero net lift. The flutes on the throwing stick seem to be the optimum roughness to maximise drag reduction benefits.

The use of roughness elements in pre-European Australia (flutes in this case) appears to be consistent with their use in contemporary times as a technology for enhancing aerodynamic performance. Fact must, however, be separated from conjecture. It is fact that the fluting improved the performance of these artefacts as hunting tools and fighting weapons. As to whether there was an empirical process that resulted in a conscious decision to keep the flutes for this purpose is in the realm of conjecture, because the same flutes are on items that had no aerodynamic requirements, such as wooden bowls. However, there is the possibility that, along with many early inventions, the fluting was a serendipitous discovery implemented for advantage.

If the fluting on a boomerang created too much lift near the outer tip, a larger than desired precessional moment would be generated and the boomerang would climb excessively. This can be remedied by omitting the fluting near the tips. Perhaps this accounts for those boomerangs similar in all respects to that shown in Fig. 1, but with fluting only over about the middle one third of the longitudinal length. The precessional moment can also be reduced by the negative twist often present on hunting boomerangs.

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REVISION OF AUSTRALIAN *CHAETARTHRIA* STEPHENS (COLEOPTERA: HYDROPHILIDAE).

BY C.H.S. WATTS

Summary

WATTS, C.H.S. (2000). The genus *Chaetarthria* in Australia is revised. The synonymising of *Chaetarthria australis* Knisch and *C. sjostedti* Knisch with *C. nigerrima* (Blackburn) by Balfour-Browne is confirmed. This species is the only one present in Australia. It is patchily distributed in coastal northern and eastern Australia.

REVISION OF AUSTRALIAN *CHAETARTHRIA* STEPHENS (COLEOPTERA: HYDROPHILIDAE)

C. H. S. WATTS

WATTS, C. H. S. 2000. Revision of Australian *Chaetarthria* Stephens (Coleoptera: Hydrophilidae). *Records of the South Australian Museum* **33**(1): 29–31.

The genus *Chaetarthria* in Australia is revised. The synonymising of *Chaetarthria australis* Knisch and *C. sjostedti* Knisch with *C. nigerrima* (Blackburn) by Balfour-Browne is confirmed. This species is the only one present in Australia. It is patchily distributed in coastal northern and eastern Australia.

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Manuscript received, 22 October 1999.

The hydrophilid genus *Chaetarthria* Stephens, 1835 contains numerous species, predominantly in the Neotropical and Neartic regions (Hansen 1991). The extensive New World fauna has been reviewed by Miller (1974) and Spangler (1977). In comparison the Australian fauna is depauperate with only one recognised species, *C. nigerrima* (Blackburn, 1891), although two others, *C. sjostedti* Knisch, 1922a and *C. australis* Knisch, 1922b, have been described. None are described from nearby Indonesia or New Guinea but I would expect the genus if not the species to also occur there. Apart from the original descriptions nothing has been written on the Australian species.

The genus belongs in the tribe Chaetarthriini, readily recognised by their globular shape and either divided eyes or the first and second ventrites having a large cavity normally filled with a hyaline mass and covered by long setae arising from the front edge of the first ventrite (Hansen 1991). The tribe is represented in Australia by two genera: *Amphiops* and *Chaetarthria*. From *Amphiops, Chaetarthria* can readily be separated by their undivided eyes, small size (< 2.0 mm.) and, in the Australian species at least, virtual lack of punctures.

The collections from which specimens were examined are listed under the following abbreviations:

ANIC	Australian National Insect Collection, CSIRO, Canberra
BMNH	Natural History Museum, London
MV	Museum of Victoria, Melbourne
NTM	Northern Territory Museum, Darwin
NRS	Naturhistoriska Riksmuseet, Stockholm
SAMA	South Australian Museum, Adelaide
DPIM	Queensland Department of Primary Industries, Mareeba.
UQIC	University of Queensland Insect Collection, Brisbane

SYSTEMATICS

Genus *Chaetarthria* Stephens, 1835

Chaetarthria nigerrima (Blackburn,1891)

Paracymus nigerrimus Blackburn, 1891.

Chaetarthria nigerrima (Blackburn, 1891); J. Balfour-Browne, 1938; Gentili, 1993.

Chaetarthria australis Knisch, 1922b; J. Balfour-Browne, 1938.

Chaetarthria sjostedti Knisch, 1922b; J. Balfour-Browne, 1938.

Types

Paracymus nigerrimus Blackburn. *Lectotype*: 'Australia Blackburn Coll B.M. 1910-236' 'Paracymus nigerrimus, Blackb' 'T 3566' BMNH. Blackburn gave the locality as 'Mountains of Victoria' in his original paper. Herein designated.

Chaetarthria sjostedti Knisch. *Lectotype*: 'Malanda' 'Queensl. *Mjoberg*' 'Type' 'Chaetarthria Sjostedti m. Nsp. A.Knisch 1921' '5348 E91 +' with red TYPUS label, NRS. Herein designated.

Paralectotypes: 1, 'Ma-landa' 'Queensl. *Mjoberg*' '5347 E91+, (missing head and thorax), NRS. 1, '3566' 'Victorian Alps Blackburn' 'Paracymus nigerrimus, Blackb. Co-type', SAMA. Herein designated.

Chaetarthria australis Knisch. Syntypes: Not located. Type locality given as Gayndah, Queensland. Knisch 1922b gives the locations of the types as Museum Godeffroy No 10696 and 10701 and a further example in the Hamburg Museum.

Description (number examined, 296) Fig. 1

Length 1.5–2.5mm. Round, deep bodied, height of elytra a bit less than half length; dorsal surface shiny black, sides of pronotum, edges of elytra and apex of elytra light testaceous-yellow, ventral surface dark-testaceous, appendages a little lighter.

Dorsal surface: Head relatively narrow, sides converging somewhat in front of eyes, finely reticulate, very weakly punctate; labrum large, front edge straight or very weakly concave, with moderate punctures stronger than on rest of head. Pronotum smooth apart from weak fine microreticulation and sparse weak punctures at sides and along front margin, disc virtually impunctate. Elytron shiny, microreticulation weak, about twenty rows of serial punctures (these are very weak and hard to trace other than from the ventral surface with transmitted light), sutural groove strong in apical half, then progressively weaker forwards but still traceable almost to scutellum.

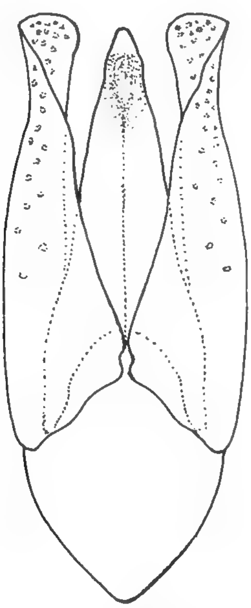

FIGURE 1. Dorsal view of aedeagus of *Chaetarthria nigerrima* (Blackburn) from Millstream, W.A.

Ventral surface: Shiny, microreticulation weak; metasternum with quite strong setae in middle; first ventrite with confluent row of very long, strong, golden setae along front edge reaching to third ventrite, a similar row of much shorter setae on rear edge of second ventrite pointing backwards, short inward-pointing setae at sides of second ventrite; other ventrites with quite dense covering of short setae/spines except for front half of third ventrite; epipleuron broad in front, rapidly narrowing to middle, absent behind, almost in same plane as sides of elytron.

Appendages: Maxillary palpi relatively short, apical segment about 2.5 times length of penultimate, with 3–5 small, elongate sensillae on the outside at base. Protibia relatively narrow, parallel-sided for most of length, with numerous blunt spines towards apex but without modified setae; procoxa with around eight strong spines on ventral surface near base. Ventral surface of pro- and mesofemora covered with short golden setae except close to base, metafemur without such setae except along front edge.

Male: Basal piece of aedeagus short, paramere tips flared, truncated, apical portions and inner edges semi-membranous and less chitinised than rest of paramere (Fig.1).

Remarks

Chaetarthria nigerrima has a wide distribution around northern Australia from the Pilbara region of Western Australia to eastern Victoria. It is not common but when present is often abundant in a small area. I suspect that the species might be semi-colonial. One such aggregation that I found in the Northern Territory was living in small tunnels in wet sand just above, and possible also below, the waterline at the edge of a sandy pool in a drying river bed. Other specimens are recorded as having been collected among gravel at the water's edge. It also comes to light which is how most of the specimens were collected. Miller (1974) likewise recorded the genus in North America as predominantly living in sand and gravel at the edge of still or relatively still water, and also flying to light. The larva of *C. nigerrima* is unknown but that of the European *C. seminulum* Herbst, 1797 has been described by Böving and Henriksen (1938).

Knisch, who was unaware of Blackburn's species, described two additional species, one from Gayndah, Queensland and the other from Malanda, Queensland. The type of *P. nigerrimus* Blackburn and the type of *C. sjostedti* belong to the same species. The types of *C. australis* would appear to have been lost but there is nothing in the description that would clearly distinguish it from *C. nigerrima* and this and the fact that all modern specimens appear to belong to the one species lead me to agree with Balfour-Browne (1938) that *C. australis* Knisch, 1922b is a junior synonym of both *C. nigerrima* (Blackburn) and *C. sjostedti* Knisch, 1922a.

Note on priority: The description of *C. sjostedti* was published on the 24th of January 1922 (Knisch 1922a), not in 1921 as given in Knisch 1924. In June the same year Knisch published the description of *C. australis* and at the same time also reprinted his earlier description of *C. sjostedti* (Knisch 1922b) as a new species.

Distribution

Australian Capital Territory: Bendora Dam, ANIC; Black Mountain, ANIC. **New South Wales:** 17 km SE Braidwood, ANIC; Cabbage Tree Creek, Canberra-coast road, ANIC; Chichester State Forrest, ANIC; Valery, ANIC. **Northern Territory:** Bessie Springs, ANIC; Nourlangie Creek, 20 km SSW Jabiru, SAMA; 19 km E by S Mt Borradaile, ANIC; Muirella Park, Kakadu National Park, DPIM; U. D. P. Falls, Kakadu National Park, NTM; Upper South Alligator River, ANIC. **Queensland:** Bushland Beach, 20 km N Townsville, SAMA; Bushy Creek, Mossman-Mt Lewis road, ANIC; Cairns District, SAMA; 25 km N Cooktown, ANIC; 30 m N Cooktown, UQIC; 70 km SW Greenvale, SAMA; Henrietta Creek, Palmerston National Park, UQIC; Iron Range, DPIM; Kennedy Creek S of Laura, DPIM; 25 km N Laura, DPIM; Kuranda, ANIC; 30 km W Laura, DPIM; 22 km S Mareeba, DPIM; Millaa Millaa Falls, UQIC; Mossman-Mt Lewis road near Julatten, ANIC; Mt Surprise, DPIM; 22 km N Mt Molloy, ANIC; North Pine River, UQIC ; Palmerston National Park, UQIC; 15 km NNW South Johnstone, DPIM; 20 km S Townsville, SAMA; Stewart Range, SAMA; Walkamin, DPIM; Windsor Tableland, DPIM. **Victoria:** Genoa, ANIC; Meredith, MV; Victorian Mountains, BMNH. **Western Australia:** Fitzroy River, ANIC; Millstream, ANIC; 1 km N Millstream, ANIC; Wittenoom Gorge, ANIC.

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WORDS TO OBJECTS: ORIGINS OF ETHNOGRAPHY IN COLONIAL SOUTH AUSTRALIA.

BY PHILIP G. JONES

Summary

JONES, P.G. (2000). During the two decades preceding the establishment of the South Australian Museum in 1856, colonial ethnography was an ill-defined project, influenced by the diverse aims of social philanthropists, Christian missionaries and those intent upon creating optimum conditions for the colony's economic growth. This paper notes the significant role of individual ethnographers such as Eyre, Grey, Angas and Cawthorne in producing descriptive ethnographies and in collecting associated series of artefacts for a British, rather than a local Australian public. This factor slowed any impetus towards a local ethnographically-oriented museum. The paper documents another factor; the efflorescence in philological studies of South Australian languages during the 1830s and 1840s, which overshadowed local interest in assembling museum collections of ethnographic material.

WORDS TO OBJECTS: ORIGINS OF ETHNOGRAPHY IN COLONIAL SOUTH AUSTRALIA.

PHILIP G. JONES

JONES, P. G. 2000. Words to objects: origins of ethnography in colonial South Australia. Records of the South Australian Museum **33**(1): 33–47.

During the two decades preceding the establishment of the South Australian Museum in 1856, colonial ethnography was an ill-defined project, influenced by the diverse aims of social philanthropists, Christian missionaries and those intent upon creating optimum conditions for the colony's economic growth. This paper notes the significant role of individual ethnographers such as Eyre, Grey, Angas and Cawthorne in producing descriptive ethnographies and in collecting associated series of artefacts for a British, rather than a local Australian public. This factor slowed any impetus towards a local ethnographically-oriented museum. The paper documents another factor; the efflorescence in philological studies of South Australian languages during the 1830s and 1840s, which overshadowed local interest in assembling museum collections of ethnographic material.

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Philanthropists And Fringe Dwellers

Meeting in London during 1834, the South Australian Literary and Scientific Association had shown an interest in Australian Aborigines even before the new colony was proclaimed. Expressed in lectures on the phrenological and physiological character of the Aborigines, or their treatment at the hands of British colonists, this interest had less to do with ethnographic theory than with colonialist practice. Phrenological technique was perceived as a means, not only of discovering more about a strange people for the sake of science, but also of managing these encounters more efficiently and, if possible, more humanely than on the colonial frontiers of New South Wales or Tasmania (Reece 1974: 85–93). South Australia's Adelphi planners were aware that their treatment of the Aborigines would test their stated humanitarian objectives for the new colony.

South Australia's first Chief Justice stated the case in these terms: 'The system hitherto adopted in the immediate neighbourhood of this Province, towards the native population, is one at which humanity shudders ... But such is not the system which will be adopted towards them here, where I trust, under Providence, that a new era is about to dawn for them'.[1] Interestingly, this opinion was expressed in an 1837 court case in which two white men had been charged with the theft of a jacket and some 'warlike implements (spears and waddies) from some of the aboriginal inhabitants of this Province'—one of the first documented cases of direct appropriation of Aboriginal artefacts in South Australia.[2] This optimism prevailed at least until 1839 when the *Southern Australian* expressed the view that '[f]or the first time in the history of colonisation, the civilised and uncivilised man have met without collision, and emigration has brought with it a blessing rather than a curse'.[3]

By 1841, following the massacre of the 'Maria' shipwreck survivors and the Rufus River affray, attitudes of South Australian colonists towards Aborigines had noticeably hardened (Pope 1989). Controversy surrounding the legality of the *ex judice* executions of two Coorong Aboriginal men for their part in the 'Maria' massacre helped to crystallise the new status of South Australian Aborigines as British subjects (ibid 144–45). With the privileges attached to this legal standing, such as the capacity to serve as witnesses in criminal

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[1] Sir John Jeffcott, address to Grand Jury, quoted in the *Register*, 3 June, 1837, p.5.

[2] *Ibid:* 4–5. The offence was committed in an Aboriginal hut at Glenelg.

[3] Editorial comment, *Southern Australian*, 16 June, 1838, p.4.

trials, came an entanglement of legal regulation directed at defining and circumscribing Aboriginal autonomy and movement in the Adelaide region. As Colonel Light's grid of streets and squares took shape, so Aboriginal hunting and gathering practices near settled areas became increasingly problematic. Aborigines were drawn into the local European economy and their previously unfettered range was restricted to defined living areas such as the 'Native Location' or semi-permanent camps such as those at Glenelg or at Kensington.[4]

During 1847 a plan was drawn up to create restricted areas within the city's parklands for the Aborigines and their 'wurlies'.[5] Aboriginal children were encouraged or coerced into the missionaries' day school, while their parents were engaged as hewers of wood and fetchers of water. As early as 1839 Robert Gouger had observed that 'a little sugar, biscuit, or bread is sufficient inducement for them to bring wood, water or stone for building, and several instances have occurred of ten or twelve of these poor fellows working during six hours consecutively for an individual for biscuit [sic]'.[6] During 1840 the *Adelaide Chronicle* published an article discussing a 'scheme for the indoctrination of industrious habits amongst the Aborigines'.[7] Three years later, 'the best means of civilising Aborigines' was discussed at one of the early meetings of the Adelaide Literary and Scientific Association and Mechanics Institute, the precursor of the colony's Library and Museum.[8]

Aborigines in colonial Adelaide had been effectively marginalised by the later 1840s. The frontier, and the danger which it represented to the young and vulnerable capital, had receded beyond everyday sight and discussion. This period saw the image of the ignoble mendicant and the 'comic savage' displace that of the noble savage encountered by South Australia's First Fleet. Edward Snell's first impression of Adelaide Aborigines in 1850 reveals this shift: 'Plenty of natives stalking about the streets half naked—most of the women with nothing on but a blanket and nearly all of them the ugliest wretches it is possible to conceive' (Snell 1988: 49).

The progression in European depictions of the Aborigine observed by Bernard Smith for Sydney's first two decades is also evident in Adelaide (Smith 1984: 174–75, 220–21). With the increasing tendency to reduce Aborigines to stereotypes in commentary, journalism and art, came an inclination to apply more general policies which took even less account of specific Aboriginal requirements. Of course this trend was not universal; the exotic character of Aboriginal life remained an important ingredient of colonial Adelaide for at least a decade after settlement. Images of the noble savage continued to surface—at the *palti* or *kuri* dances held at full moon, or on the battlefield during periodic confontations between the Adelaide, Encounter Bay, and River Murray groups. Even these occasions were subject to European surveillance or control; the corroborees were usually attended by European voyeurs (invited or not), while the battles were often either terminated or forestalled altogether by police intervention.[9] One of William Cawthorne's most telling watercolour depictions of the Aboriginal subject at this time was his study of a pile of decorated shields and spears, smashed by police horses to prevent tribal fighting near Adelaide.[10] Cawthorne was sufficiently disturbed by this event to write an article for the *Register*, on behalf of one of the principal Adelaide elders, King John (Mullawirraburka):

> On Monday last, a fight was to have taken place between Moorundee, Encounter Bay, and Adelaide natives. Great preparations are accordingly made. The young men were all in high glee—tattooed [printed in error for 'karkooed', ochred], oiled, and all ready for the coming amusement, but unfortunately they were disappointed; for, as they were marching to meet each other on the old Bay

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[4] See Foster 1991. For example, in June 1837 the Protector of Aborigines noted that he had removed 'certain Aborigines who had settled on Dr Wright's town acre' and a few weeks later John Morphett complained that Aborigines were cutting down trees on his town acre (GRG 24/1/1837/210; 246). In December 1838, the Superintendent of Police reported the 'habit of the Aborigines of disfiguring trees in the Park Lands, yet during the same year colonists were employing Aborigines to remove timber from the same areas (GRG 24/4/1838/20; 24/1/1838/8, SRO). For a broader discussion of this issue, see Reynolds (1990: 129–163).

[5] GRG 24/61847/440, State Records, South Australia

[6] Gouger 1838: 56. By 1847 Adelaide Aborigines were being employed to break stones for paving the city's streets (GRG 19 24/4/1847/273, State Records, South Australia).

[7] *Adelaide Chronicle*, 18 & 25 February, 1840, p.3; p.2.

[8] The meeting canvassed a range of strategies, ranging from the establishment of a native police force to the dual operation of a 'House of Correction' and a 'Native Location'. See the *Southern Australian* 28 February, 1843, p.2; *Adelaide Examiner* 25 February, 1843, pp.3–4.

[9] See Angas (1847a, vol.1: 102–108) and Leigh (1839: 143) for descriptions of corroborees attended by Europeans at this time.

[10] Cawthorne Diary, Monday, 22 April, 1844, Foster (ed.) 1991: 46. The original drawing is contained in the Cawthorne mss., Mitchell Library, Sydney

> road, three horse-police very unceremoniously stopped them, and had every spear and shield laid on the ground, and broken up. The astonishment that this act produced, was truly remarkable—some looked quite aghast, others were confounded, and many for the moment, I dare say, doubted their senses, whether such a collection of beautiful uwindas and shields, kylahs and midlays, were absolutely to be destroyed.[11]

By the later 1840s these events, and Aborigines themselves, had become no more than a picturesque backdrop to the bustling activity of colonial Adelaide. Already in 1843 Aborigines were tried for 'appearing naked' in Gawler Place. 'Sunday corroborees' were finally forbidden during 1847.[12] The careful, individual portraiture of George French Angas and William Cawthorne was gradually supplanted by the caricatures and drawings of S. T. Gill, Alexander Schramm, and Edward Snell, or by landscape painting in which 'the aborigine [was] relegated increasingly to fulfil the function of a pictorial embellishment to topographic landscape, providing a local touch and pointing the contrast between primeval life and the busy progress of the town'.[13]

During the years following European settlement the curiosity value of Aboriginal objects, like their owners, steadily diminished. Familiarity bred contempt. Some collections of Adelaide Plains artefacts continued to make their way to Europe, evoking, like trophy displays, the raw experience of the colonial frontier, but little attention was paid to the preservation or classification of such artefacts in Adelaide itself during the 1840s or 1850s. A factor of some significance, particularly in the light of the marked effect on local collecting practice triggered by the demand for Aboriginal artefacts for the International Exhibitions of the 1870s, may lie in the British Museum's focus (and that of British collectors) on the Assyrian antiquities, first acquired in 1849 (Bohrer 1994). The British Museum's preoccupaton with antiquities during the late 1840s and 1850s may well have been mirrored in colonial Australia, to some extent.

Despite the pioneering roles of Governors Gawler and Grey, the exigencies of colonial life in Adelaide meant that the practice of ethnography was important only so far as it contributed to the colonists' image of a new and strange land, or to an overlapping phase in which it was necessary to understand the Aborigines in order to control them more effectively. The early descriptions of Aboriginal life in South Australia and the published lithographs of watercolour studies by Angas catered for the first category of interest, primarily directed to a British readership. The ethnography of the missionaries and early Protectors such as Wyatt and Moorhouse was directed towards the more practical ends of the second phase. Moorhouse's Murray River vocabulary (1846) was constructed well after his Adelaide work, and was made at Grey's behest. In this sense it does not provide an exception to the general rule, by which other ethnographers followed their publications on grammar and vocabulary with more discursive works on manners and customs. Moorhouse and Teichelmann produced a joint 'Report on the Aborigines of South Australia' (published in January 1842) and Moorhouse was solely responsible for the 'Annual Report of the Aborigines' Department' (unpublished until 1991, see Foster 1991). The concentration of ethnographic research and publication in Adelaide during this second phase was markedly higher than in other colonies, a fact which throws the decline in ethnographic enquiry during the 1850s and 1860s into greater relief. Following the publication of Moorhouse's vocabulary in 1846, eighteen years passed before the next South Australian linguistic publication appeared—George Taplin's first work on Lower Murray River languages (1864).[14]

The reasons for this concentrated burst of activity are two-fold. In the first place, because of the concern expressed in England during the late 1830s by Lord Glenelg and the Colonial Office about the mistreatment of indigenous peoples, and partly because of the concentration on this issue by the key individuals associated with the colony of South Australia, Aboriginal matters were of greater concern for South Australian policy-

[11] *Register*, 24 April, 1844, p.3. See also *Adelaide Observer*, 27 April, 1844, p.5.

[12] *Southern Australian* 5 September, 1843, p.2; GRG 24/4/1847/195; 205; 1430; 1462, State Records, South Australia.

[13] Smith 1984: 220. Smith makes this point in relation to Sydney artists of the 1790s and 1800s; the same shift can be observed in Adelaide's colonial period, three decades later. See also Dutton (1974).

[14] Teichelmann produced an unpublished, extensive, revised version of his Adelaide vocabulary during this period; this was sent to George Grey in Cape Town in 1857 (Teichelmann 1857 ms.). The vocabulary published by E. M. Curr in 1886 (Teichelmann, Schurmann & Wyatt 1886) is a much shorter wordlist.

makers.[15] This sensitivity accounts for the extended but ultimately unsuccessful efforts to fill the post of Protector of Aborigines with the 'conciliator' of Tasmanian tribes during the 1820s, George Augustus Robinson.[16] It also explains the trouble to which George Fife Angas went to secure the services of Lutheran missionaries prepared to learn the languages of the South Australian Aborigines in order to impart Christian principles to their children. In their attempts to explore the mental world of South Australian Aborigines, Teichelmann, Schurmann and Meyer went further than assembling simple word lists. Their expanded publications on the 'manners and customs' of Aborigines of Adelaide, Port Lincoln and Encounter Bay followed their scholarly work on the languages of these groups. For example, Teichelmann and Schurmann's grammar and vocabulary of the Adelaide Aborigines (1840) preceded Teichelmann's work on their manners and customs (1841) published in the following year, and Schurmann's vocabulary of the Parnkala people of Spencer's Gulf (1844) preceded his general work on the Aborigines of Port Lincoln (1846). Schurmann's ethnographic work with Port Lincoln Aborigines can be regarded as part of his duties as Protector of Aborigines there. Meyer's vocabulary of South Australian Aborigines (1843) preceded his work on the manners and customs of Encounter Bay Aborigines (1846).

Philology And 'The Abstract Science Of Man'

For a decade following the creation of the colony in 1836, the level of South Australian ethnographic activity exceeded that of any other colonial outpost throughout the world. At least thirteen vocabularies, four grammars and six descriptive works on South Australian Aboriginal manners and customs were produced. The vocabularies were by Bromley, Stevenson and Finlayson (unpublished and untraced); Gell (Assistant Secretary to Governor Gawler) 1841; Meyer (1843), Moorhouse (1846), Piesse (1840), Schurmann (1844), Teichelmann (Teichelmann, Schurmann and Wyatt 1886), Teichelmann and Schurmann (1840), Weatherston (n.d.; see Hunt (1985: 38)), Williams (1839), Wyatt (Teichelmann, Schurmann and Wyatt 1886). The descriptive ethnographies were by: Angas (1847a; 1847b), Cawthorne (1926), Eyre (1845), Grey (1841a), Meyer (1846), and Schurmann (1846). Schayer's (1844) Berlin publication on the language, manners and customs of South Australian Aborigines was probably based on the work of the Dresden missionaries. In addition, it appears that other concerted ethnographic and linguistic work was undertaken, such as that by the surgeon Richard Penney in 1841 and by the police-trooper and Sub-Protector George Mason during the early 1840s (Lendon 1929: 24: & 31: 20–33). Proportionately, this level of output in Australian linguistics has not been equalled since.[17]

South Australia's evolution as a colony coincided with the early development of ethnography as an internationally accepted scientific discipline. The first documented use of the term 'ethnography', to mean 'the scientific description of nations or races of men, their customs, habits and differences' was in 1834, the foundation year of the South Australian Literary and Scientific Association.[18] From the beginning though, ethnography was far more than a descriptive exercise: like other branches of Enlightenment natural science it held great promise as a means of discerning the origins of humankind. Australian Aborigines provided a new and exciting field for ethnographers, but seldom as a people to be studied in their own right. Their primary ethnographic value lay in the data which an analysis of their characteristics could contribute to wider debates.

The focus of ethnographic study shifted back and forth several times during the nineteenth century, from physical description to philology, to

[15] The correspondence files of the South Australian Company, particularly those of its Director, George Fife Angas, are full of references to this crucial issue (PRG 174, Mortlock Library, Adelaide). See also further discussion of this point in Pope (1989). Following the recommendations of the 1837 'Report from the Select Committee on Aborigines' (1968 (1837)), Standish Motte (himself a member of the South Australian Literary Association), published his 'Outline of a System of Legislation for Securing Protection to the Aboriginal Inhabitants of All Countries Colonized by Great Britain' (Motte 1840).

[16] John Brown, a founding committee member of the South Australian Literary and Scientific Association in London, was a cousin of the celebrated missionary George Augustus Robinson who worked among Tasmanian Aborigines during the 1830s. During 1836 Brown agitated successfully for Robinson to become South Australia's Protector of Aborigines, but Robinson eventually decided against the position.

[17] The 1960s–70s produced a very high volume of linguistic publications but from a much wider pool of specialists (J. Simpson pers. comm. 1991).

[18] 'The Shorter Oxford English Dictionary': 685.

kinship studies and religion, to archaeology and material culture. Internationally, the emphasis during the first half of the century centred firmly on philological research.[19] This promised a level of methodological certainty and a potential for deductible results which other branches of anthropology lacked. For newly arrived settlers in the New World and Australia the question of how the native inhabitants came to be there was of particular interest. Posing this question in his 'Notes on the State of Virginia' in 1804, Thomas Jefferson had predicted that language would offer 'the best proof of the affinity of nations which can ever be referred to'. Forty-two years later, Henry Schoolcraft's 'Plan for the Investigation of American Ethnology', presented to the Smithsonian Institution in 1846, stressed the resilience of this notion:

> Philology is one of the keys of knowledge which, I think, admits of its being said that, although it is rather rusty, the rust is, however, a proof of its antiquity. I am inclined to think that more true light is destined to be thrown on the history of the Indians by a study of their languages than of their traditions, or of any other feature (Jefferson and Schoolcraft quoted in Hinsley (1981: 23).

Comparative philology had the added advantage of offering a method for tracing the origins and diffusion of the world's peoples within the relatively short chronology accepted within biblical orthodoxy. South Australia's third Governor, George Grey, was a significant contributor to debate on this subject, which remained the 'queen of the human sciences' until the late 1850s, when biblical chronology was undermined by the emerging acceptance of Darwinian theory, geological time and the new 'prehistoric' archaeology (Chapman 1985: 21–22; Crawfurd 1863). In the meantime though, the careful, scientific methodology of philologists such as Johann Forster, Samuel Marsden, Lord Monboddo, and Wilhelm von Humboldt paralleled the techniques employed by the rising generation of earth scientists, future evolutionists included. Charles Darwin's influential friend, the geologist John Herschel, drew the analogy: 'Words are to the Anthropologist what rolled pebbles are to the Geologist—battered relics of past ages often containing within them indelible records capable of intelligible interpretation' (Desmond and Moore 1992: 215).

In Adelaide during the 1840s the science of philology held similar promise for the colony's 'utopian socialists'. Addressing an audience of 1 000 in the Queen's Theatre, even the austere Advocate-General, William Smillie, reserved a prominent place for philological studies in Adelaide's cultural life:

> The student of human nature will also find an appropriate chapter on the *aborigines*. Many of their peculiar customs and superstitions, the analogical sense contained in their terms, and the structure of their speech, illustrate the abstract science of man, while etymologies may be collected to throw some light on their origins and history, as connnected with other races... (Smillie 1842: 437).

Another of South Australia's 'utopian socialists', Robert Gouger, devoted considerable space to the Aborigines in his publication about the colony, referring to the linguistic similarity between South Australian Aborigines and the 'Malays of Dampier Straits' as perceived by Mr Donovan, chief officer of the *Katharine Stewart Forbes* (Gouger 1838: 52–53). The emerging science of ethnography drew its data neither from social traits nor from a comparison and analysis of material culture, but from linguistic 'specimens'. All the attributes of scientific practice were satisfied by the new field of linguistics. Given the correct direction and technique, useful data could be gathered by amateurs who would gain the reward of knowing that each fragment collected would assist their scientific mentors in constructing a new picture of human origins. Unlike collectors of ethnographic objects, whose arrays of curiosities still bore no evident relation to European artefacts, amateur and scientific linguists shared the conviction of natural scientists that they were actively collaborating in a grand scheme.

With the decline of philological research and deductive enquiry after mid-century, more tangible types of evidence seemed called for. The historian William Chapman has noted that for some, 'these were the evidence of skeletal and cranial forms, either as measured or uncovered from the ground; for others, the evidence of archaeology more generally; but for Pitt Rivers, the privileged evidence was to be that based on the comparison of artifacts' (Chapman 1985: 22). Even so, ethnographic collecting did not achieve quick popularity. It was not until the final decades

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[19] See Gascoigne (1994: 160–176) for an account of philology within the Enlightenment context.

of the century that the role of Australian museums as repositories for ethnographic objects came to be validated in terms of the contribution which those objects might make to the pursuit of ethnography, or to science in general. During the decade after South Australia's proclamation, the collection of linguistic information had been validated in just those terms. As an 'exact science of mental objects', philology provided the impetus for the first systematic application of Western scientific principles of classification to Aborigines. As the French philosopher Renan put it, philology was a scientific method to be used for arriving at 'the very system of things ... [it is] ... the exact science of mental objects. It is to the sciences of humanity what physics and chemistry are to the philosophic sciences of bodies (Renan 1890 (1848): 149).

The multitude of Aboriginal vocabularies and basic grammars collected from the colonial frontier during the middle years of the nineteenth century can be contrasted with the relatively casual collection of Aboriginal artefacts during the same period. Susan Pearce has suggested that such an inverse relationship between language and objects may have been characteristic of this era, implicit in the dual status of ethnographic objects as both 'real' and 'constructed' artefacts:

> The long-term trend of European thought, increasingly cogently expressed from the late seventeenth century onwards, is to give a low value to the material world as such, and to regard it as the fit place for the exercise of human reason and enquiry through which real knowledge will be constituted. On this reading, objects in general are the passive result of social action, and museum collections enshrine the results of objective enquiry which has yielded real understanding; in other words, the metaphorically constructed understandings have been seen as superior to the concrete, contextual reality of the things. An important aspect of this is the tendency to regard language, the prime medium for classification and reason, as the faculty which creates social structure, although as we have seen there is not an exactly parallel relationship between language and the material world (Pearce 1992: 257).

The rigour which characterised linguistic studies in this early period has its direct analogue in natural science, as Edward Said has observed:

> Science gives speech to things; better yet, science brings out, causes to be pronounced, a potential speech within things. The special value of linguistics (as the new philology was then often called) is not that natural science resembles it, but rather that it treats words as natural, otherwise silent objects, which are made to give up their secrets. Remember that the major breakthrough in the study of inscriptions and hieroglyphs was the discovery by Champollion that the symbols on the Rosetta Stone had a phonetic as well as a semantic component. To make objects speak was like making words speak, giving them circumstantial value, and a precise place in a rule-governed order of regularity (Said 1978: 140).

But this 'circumstantial value' was not attached to ethnographic objects by museum scientists until the third quarter of the nineteenth century. The shift of status which eventually occurred during that period is best symbolised by the replacement of the descriptive term 'curio' by the phrase 'ethnographic specimen', carrying the implication that the classifications and strategies applied to natural objects by museum scientists could equally be applied to artefacts. Until that point was reached philology or linguistics remained the only branch of ethnography accorded scientific status. With few exceptions this field remained beyond the confines of the newly established natural history museums in Europe and Australia.

South Australia's early ethnographic studies, and similar researches in other Australian colonies, have been enlisted by historians of anthropology in describing the developing picture of the country's anthropological discipline (See for example, McCall 1982; Mulvaney 1964; 1993; Peterson 1990; Tindale 1986). In his subdivision of Australian anthropological history, A.P. Elkin placed the work undertaken during the colonial period within an 'incidental phase', implying little continuity with succeeding periods (Elkin 1970: 6; 1963). McCall (1982) and Peterson (1990) accept this characterisation of early Australian anthropology. While there is no doubt that later ethnographers and anthropologists built upon the results of this early work, the phase does bear a distinct character, apart from the sense employed by Elkin. The phase can be distinguished by the pragmatic, utilitarian nature of the research which it generated. Almost all of the ethnographic pamphlets and booklets appearing in Adelaide during the 1840s were published in the name of science. Most of this output was directed towards practical, short term ends; to facilitate the tasks of administrators and missionaries in dealing with Aborigines in the colonial situation. This early ethnographic work can be regarded as a precursor of the applied anthropology undertaken for colonial administrations during the early twentieth century.

Each of the early Protectors of Aborigines produced vocabularies of the Adelaide Plains or adjoining regions, not primarily as a contribution to the growing international corpus of such material, but as a means of undertaking their assigned duties. The English Parliamentary Select Commission on Aborigines (British Settlements) of 1837 had officially recommended that Protectors of Aborigines 'should be expected to acquire an adequate familiarity with the native language' and that 'the Protectors should be furnished with some means of making to the tribes occasional presents of articles either of use or ornament' ('Reports from the Select Committee on Aborigines'. 1968 (1837), vol.2, p.83). By the time that this directive was issued, South Australia's first two Protectors, George Stevenson and Captain William Bromley, had already prepared working vocabularies. By August 1837, when Bromley was replaced by William Wyatt, the colonial government had adopted the Select Commission's directive regarding Aborigines and advised the new Protector that 'no time should be lost in acquiring a knowledge of their native tongue'.[20]

Wyatt and his successor Matthew Moorhouse prepared vocabularies of the Adelaide and Murray River Aborigines (Wyatt 1879, 1886; Moorhouse 1846).[21] The Governor's secretary wrote to Wyatt in August 1839 following the Protector's enforced resignation, informing him that the governor 'had peculiar opportunities for observing the patient and scientific research with which you have investigated their language, and he has now in his possession an extensive and very valuable vocabulary of it compiled by you' (Lendon (n.d.) ms.: 212).

The Colonial Storekeeper, William Williams, who also collected Aboriginal artefacts at this time for the Colonization Commissioners, recognised the utility of publications which might assist government officials and employers to benefit from the labour of 'idle natives', while encouraging the civilising process. During early 1839 he compiled his own vocabulary of the Adelaide Aborigines and offered this for sale to subscribers, including Governor Gawler and other government officials and notables.[22] Until his removal from office in 1841, Gawler played a vital role in sponsoring ethnographic studies of this kind, encouraging and assisting the work of the Protectors (notably Moorhouse), the Lutheran missionaries, and Edward John Eyre.

The arrival of George Grey during 1841 to replace Governor Gawler lifted South Australian ethnography out of its short-term, utilitarian mould. An influential anti-slavery and Church Missionary Society advocate, the young cavalry captain had already undertaken substantial ethnographic and linguistic studies of Western Australian Aborigines before his South Australian appointment (Grey 1841a). On the basis of his Western Australian experiences he had written carefully on the issue of 'promoting the civilisation' of Australia's Aborigines (1841b). In the year of his arrival in South Australia, and two years before the foundation of the Ethnological Society in London in 1843, Grey published a paper on administering native peoples, his major anthropological conclusions on Western Australian Aborigines and a detailed dictionary of South-Western Australian Aboriginal dialects (Grey 1841a; 1841b; 1841c; see also Mulvaney 1964: 23–25). During his term as South Australia's Governor from 1841 to 1845, Grey's first interest remained Australian linguistics and his 1845 paper on this subject summarised the state of knowledge in this field, noting that South Australian researchers had adopted a common system of orthography (Grey 1845). The linguistic evidence suggested to Grey that 'this continent was peopled from the north-west, and that the lines of migration were along the coast and the great water drainages of this country' (ibid: 366).

Together with Threlkeld in New South Wales, Grey was a leading Australian figure in investigating the Indo-European hypothesis of Aboriginal origins. His conclusions were reinforced with the publication of J. C. Prichard's findings that the Australian language had affinities with that of the Tamils of southern India (Mulvaney 1964: 22). He was a strong critic of inconsistent or inferior research, noting that 'up to the present time we have had only very meagre vocabularies, collected by passing strangers, each of whom adopted his own system of orthography, and the comparisons formed from such

[20] Colonial Secretary's Instructions to Protector of Aborigines, *South Australian Gazette and Colonial Register*, 12 August, 1837, p.1.

[21] Although Wyatt's vocabulary was not published until 1879, it was available for use in government circles on its completion in 1839. See *South Australian Government Gazette*, 7 June, 1839.

[22] Williams' advertisement appears in the *Southern Australian*, 27 March, 1839, p.2. A copy of this vocabulary is listed among the contents of Grey's papers held in the South African Library, Cape Town (Williams 1839). It was later published in Parkhouse (ed. 1923).

compilations must necessariy have been erroneous in the highest degree' (Grey 1841a, vol.2: 215–16). He stressed the importance of establishing consistent principles of orthography in recording Aboriginal languages as a means of adducing reliable evidence to support the Indo-European hypothesis and in this respect his encouragement of the linguistic work of South Australian Lutheran missionaries was a major contribution. This initiative began before his appointment as Governor, during his first visit to Adelaide in 1840. Tindale (1974: 3) asserts that Grey guided the Lutheran missionaries in the production of their linguistic work. Some evidence for this lies in Teichelmann's acknowledgment of discussions with Grey about Australian 'dialects' (Teichelmann & Schurmann 1840: vii, viii). But Schurmann also recorded the fact that although Grey gave valuable encouragement to Teichelmann and himself in publishing their grammar and vocabulary, it was Moorhouse who assisted in reading and editing their English text (Schurmann 1987: 104; Teichelmann & Schurmann 1840: viii). In fact, it is possible that Grey incorporated some of Teichelmann's and Schurmann's vocabulary within his own 1841 publication without acknowledgement (Grey 1841a: 212–15). Grey was also quick to adopt the modified Threlkeld 'South Sea' orthography used by Teichelmann and Schurmann in their work, and argued for its adoption by the Royal Geographical Society (J. Simpson, pers. comm. 1991).

Until Grey's arrival in South Australia the colony had no ethnographer of equivalent standing to Threlkeld, who combined local, practical linguistic studies with a commitment to ethnography as a developing international science (Threlkeld 1834: 185). By promoting ethnographic enquiry as a branch of science linked to other fields of philosophical enquiry, Grey helped to give the study of Aboriginal manners and customs a new relevance in the colony. His significance in Australian anthropological history lies in the fact that he bridged the gap between the applied ethnography of colonial administrators and the more scholarly, enquiring approach promoted by the Royal Society, subsequently adopted by both the Royal Geographical Society and the Anthropological Society of London.

Grey's style of ethnography, like that of the explorers Charles Sturt and Edward Eyre, had its origins in the British naval and exploration tradition. The Royal Society's 'Directions for Seamen, Bound for Far Voyages' were first published in 1665. Cook's instructions, based on these directions, included the obligation to 'observe the Genius, Temper, Disposition and Number of the Natives' (Smith 1984: 8,16). The earliest opportunity for British ethnographic study in South Australia arose on Matthew Flinders' voyage of exploration in 1801–2. In view of his thorough investigation of northern Australian Aboriginal implements, rock paintings and burial modes, it is unfortunate that Flinders had little contact with Aborigines in South Australia. The single vocabulary published in his expedition report was obtained at Caledon Bay, on the west coast of the Gulf of Carpentaria (Flinders 1886). The French voyage of Baudin and Peron to Australia coincided with Flinders' voyage and the two expeditions met in Encounter Bay on April 8, 1802. But the French and British observations of South Australian Aborigines were minimal in comparison to the wealth of data on Tasmanian Aborigines recorded by Baudin's expedition. As Rhys Jones has explained, during this period the French displayed a much greater commitment than the British to anthropological research, through the Societé des Observateurs de l'Homme. This is despite the fact that the Baudin expedition rarely approached the standards set in Degerando's detailed anthropological instructions and suggestions (Degerando 1969) or by Cuvier (quoted in Jones, R. 1988: 37).[23]

The earliest record of South Australian Aboriginal languages was made in Western Australia, by a colleague of Dumont d'Urville during his voyage in the *Astrolabe* (1826–29).[24] During his 1829–1830 Murray River expedition the explorer Charles Sturt made little use of his numerous opportunities to record Aboriginal language and customs, despite having been directed to 'note the description of the several people whom you may meet, the extent of their population, their means of subsistence, their genius and disposition, the nature of their amusements, their diseases and remedies, their objects of worship, religious ceremonies, and a

[23] For a useful discussion of the distinction between French and British anthropology at this time see Gascoigne (1994: 158–159).

[24] Dumont d'Urville 1830–35. Dumont d'Urville obtained his word list from a colleague, Gaimard, who had recorded several words from a South Australian Aborigine in Western Australia, possibly brought there by sealers (Simpson, 1996). See Gaimard (1833) for this vocabulary. Dumont d'Urville also made an ethnographic collection in Australia, identified by Sylviane Jacquemin and referred to in Kaufmann (1994: 125).

vocubulary of their language' (Sturt 1833, vol.1: 187–88). While he adhered to his other instructions regarding the collection and recording of natural science objects, Sturt collected very little ethnographic material and made few observations of Aboriginal life. Writing after his Central Australian Expedition of 1844–46, Sturt admitted: 'It might be thought that having been in the interior for so many months I ought to have become acquainted with many of the customs and habits of the people inhabiting it, but it will have been seen that they seldom came near us' (Sturt 1847, vol.2: 139–40):

Sturt's only records of exchange with Aboriginal people during the earlier expedition were references to bartering tomahawks, knives, pieces of iron and coloured ribbons for fish (see for example Sturt 1833, vol.1: 180; vol.2: 113). During his inland expedition though, two members of his party, Daniel George Brock and John Harris-Browne, made small collections, and part of the latter collection may have been received by the South Australian Museum in 1949.[25] Brock's contact with Aborigines on the expedition was relatively close and frequent, in contrast to his leader. Sturt's attitude towards Aborigines, like that of the influential surveyor G. W. Goyder twenty-five years later, appears to have been friendly but firm:

> if one or two of them were a little forward, I laid it to the account of curiosity and a feeling of confidence in their own numbers. But a little thing checked them, nor did they venture to touch our persons, much less to put their hands in our pockets, as the natives appear to have done, in the case of another explorer. It is a liberty I never allowed any native to take, not only because I did not like it, but because I am sure it must have the effect of lowering the white man in the estimation of the savage, and diminishing those feelings of awe and inferiority, which are the European's best security against ill treatment (Sturt 1847, vol.1: 77–78).

George Grey produced several manuscripts on Aboriginal material culture subjects, including 'basket making', 'utensils for carrying water', 'ornaments', and 'shields', presumably directed towards a major publication on South Australian Aborigines, never completed.[26] These papers were not simply descriptive. In his attempts to ascribe origins to styles and design motifs Grey prefigured the work of later ethnographers who elevated material culture studies to scientific status. Here again, Grey encouraged similar work, particularly that of George French Angas (as a protegé) and Edward John Eyre (as a rival). The twenty-three year-old Angas accompanied Grey on his vice-regal tour of the colony's south-east during January 1844, and his written observations reveal something of the more experienced ethnographer's influence. Even taking account of William Cawthorne's unacknowledged assistance, Angas's fine-grained artistic depictions of South Australian Aborigines and their artefacts set new standards for ethnographic realism within Australia. They met his stated objective of 'preserving true and life records of man and scenes, so quickly passing away ... by pictorial representation, to describe the most interesting and peculiar features of South Australia and its aboriginal inhabitants' (Angas 1847b: preface).

That verisimilitude was heightened in Angas's first major exhibition, at London's Egyptian Hall during April 1846, by the inclusion of 'costumes, implements, weapons and utensils, belonging to the Australians and New Zealanders'.[27] Angas had collected these artefacts during his travels in order to illustrate them at the journey's end. A critic from *The Times* commented on the exhibition's value as a documentary record, together with the accompanying 'antiquities': 'The views and portraits are far beyond the common class of pictures; as works of art they possess very great merit, but as connected with the antiquities and present character and manners of the country in which they were taken, they are almost invaluable'.[28]

A similar emphasis on the range and variation of Aboriginal material culture in southern South Australia was evident in Angas's narrative, 'Savage Life and Scenes in Australia and New Zealand' (Angas 1847a). The accent was further

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[25] See Jones file on the Gilbert Collection. The provenance of the collection is not clear and several objects appear to date from later in the century and from regions not visited by Sturt. Harris-Browne and his brother had pastoral interests throughout South Australia and the Northern Territory. Nevertheless, several of the objects conform to the type and style of manufacture observed for the north-east of South Australia, through which Sturt's second expedition passed during 1845.

[26] Grey manuscript collection, South African Library, Cape Town. Copies held in AIATSIS library, Canberra. The publication is referred to by William Cawthorne during 1843. See Foster (ed.) 1991: 22.

[27] *Illustrated London News*, 18 April 1846, p.253, quoted in Tregenza (1982: 13).

[28] *The Times*, 6 April, 1846, p.3c, quoted in Tregenza (1982: 17).

marked in the work of Edward John Eyre. The explorer's ethnographic investigations were advanced considerably following his appointment as Resident Magistrate at Moorundie on the River Murray in 1841. Here Eyre had the task of regulating relations between Aborigines and cattle overlanders following the bloody events of the Rufus River affray earlier in that year. Eyre used the opportunity to supplement the notes gathered on his Central and Western Australian explorations with detailed observations on the life and material culture of the Aborigines of the lower River Murray. Returning to England a matter of days before Angas's arrival in Adelaide, Eyre took with him a large collection of Aboriginal artefacts, stuffed animals, an aviary of parrots and an emu. He had also obtained the permission of his main informant, Tenberry, to take his son Warrulan and another Aboriginal boy, Koar, with him.[29] Perhaps this example provided Angas with an additional incentive to emulate the American watercolourist George Catlin's 'Indian Gallery' which had presented paintings, artefacts and Native American performers in London's Egyptian Hall during 1840 and 1841.

Many of Eyre's artefacts were collected by Edward Scott, his old friend, a fellow explorer and an associate at Moorunde. Scott shared Eyre's ethnographic interests and this collection, which included weapons, nets, fishing gear and ornaments, represented more than a casual assemblage of souvenirs. Uncertain of his next appointment, Eyre was probably serious when he informed Scott by letter that, 'when I get all odds and ends together, I shall almost be enabled to open a museum in Regent Street'.[30] Eyre's was among the first to recognise the value of collecting Aboriginal objects as empirical data which could supplement linguistic evidence for cultural origins and diversity. This recognition was at least partly inspired by George Grey. Eyre wrote:

> as Captain Grey judiciously remarks, if the comparison in such [linguistic] cases be extended, and the vocabulary of each enlarged, there will always be found points of resemblance, either in the dialects compared, or in some intermediate dialect, which will bear out the conclusion assumed. This view is still further strengthened, by including in the comparison the weapons, habits, customs, and traditions, of the various tribes ... No one individual can hope personally to collect the whole material required; but if each recorded with fidelity the facts connected with those tribes, with whom he personally came into contact, a mass of evidence would soon be brought together that would more than suffice for the purpose required (Eyre 1845, vol.2: 398, 411).

Even so, this passage makes plain the restricted, corroborative role of native artefacts in the developing science of ethnography at this time. Artefacts were still characterised as 'curiosities', not yet amenable to the levels of investigation and analysis which 'specimens of language' were receiving from philologists. Exceptions could be found: during his survey of the Australian coast undertaken between 1818–1822 Philip King collected and described material culture objects in some detail, notwithstanding the fact that his primary ethnographic instruction was to compile comparative vocabularies of all the tribes encountered.[31] Eyre's ethnography provides another significant example.

At the time of Eyre's publication, the British scientific expedition vessels H.M.S. *Fly* and H.M.S. *Rattlesnake* were cruising Pacific waters. The naturalist John MacGillivray accompanied both voyages and his Australian linguistic data gathered on the latter voyage contributed to one of the most influential works in philology, R. G. Latham's 'Elements of Comparative Philology' (1862). Despite the wealth of material culture objects encountered throughout the Pacific and northern Australia the anthropological research undertaken on the voyages was largely restricted to philology. Mulvaney notes the fact that despite the sixth volume of information published by the expedition being titled 'Ethnology and Philology', linguistics occupied all but a few pages: 'a few lines sufficed in every instance for a superficial account of the rich material culture of contemporary Pacific peoples' (Mulvaney 1964: 26). Yet just five years later in his account of the *Rattlesnake's* voyage, J. McGillivray published the first investigation into comparative material culture (Mulvaney 1964: 30). His discussion of the similarity between the Australian boomerang and an Egyptian boomerang in the British

[29] See Eyre's correspondence to E.B. Scott, August to December 1844, PRG177/2, Mortlock Library, Adelaide.

[30] ibid, 30 November, 1844

[31] Both this and the following example are drawn from Mulvaney's 1964 survey of the history of Australian anthropology (Mulvaney 1964: 18–19, 22, 26).

Museum had two effects. It signalled the admissibility of material culture data as evidence to be investigated in tracing the history of peoples. More significantly perhaps, it drew attention to the future relevance of museum collections as a site for this investigation.

Grey, Angas and Eyre helped shift the character of Adelaide ethnography from its restricted basis in administrative practice to a more empirical style linked to wider trends. Grey's and Eyre's approaches in particular foreshadowed the 'survey method' of anthropology which became so popular later in the century. In contrast to the vocabularies and short works on 'manners and customs' produced in Adelaide, the work of these individuals was published in London for a wide readership. Unfortunately for the development of Adelaide ethnography, the nature of their talents and connections made it inevitable that their stay in Adelaide would be brief. While Grey can be said to have built on the work of Governor Hindmarsh in fostering the beginnings of Adelaide anthropology, he left no successor. A gap of almost two decades separated the publications of Eyre and Angas from the next detailed research on South Australian Aborigines—George Taplin's work on the Ngarrindjeri groups.

The trio left Adelaide within months of each other: Grey to become governor in New Zealand and then South Africa, Angas to travel further and to exhibit and publish his Australian and New Zealand watercolours in London (adding a further series of South African studies during 1847), and Eyre to England before becoming a lieutenant-governor in New Zealand two years later under Grey. Each of these men had formed important collections of Aboriginal material, but almost nothing is known of the subsequent history of these objects or, indeed, of the original circumstances of their collection. This is despite their extensive writings on Aboriginal material culture.

There is little doubt that Eyre, like Angas and Grey, collected Aboriginal objects partly to illustrate subjects discussed in his publications. He may have retained several of the items figured in his 1845 two-volume account within his private collection. But he may have had an additional motive for collecting ethnographic material, linked to his official role as Protector. By 1840 his counterpart in the Port Phillip Protectorate, George Augustus Robinson, was advising his sub-protectors in each Victorian district to encourage the manufacture of native artefacts for sale through agents appointed for the purpose. A Mr Lilly, based in Melbourne, acted as the main agent for this purpose until his retirement during September 1840. By July 1840 the volume of artefacts had provoked Robinson to advise that a scale of purchase prices be devised, so that Aborigines could 'receive in provisions or useful articles the full value of the money realised ... money on no account should be given to the Natives'.[32] Following Lilly's retirement the scheme appeared to lose momentum, and Robinson advised that the 'baskets, skins and other articles ... of Aboriginal industry are in future to be retained in store at the station, until a sufficient quantity be collected for transmission to Melbourne ... to be disposed of ... either by private bargain, public auction, public bazaar, or any other mode'.[33]

Eyre's advocacy of a similar scheme suggests that he was aware of Robinson's initiatives in this regard. He wrote: 'The elder natives should be led as far as could be, to make articles of native industry for sale, as baskets, mats, weapons, implements, nets etc., these might be sent to Adelaide and sold periodically for their benefit' (Eyre 1845, vol.2: 489). The idea went no further apparently; with Eyre's departure the link between ethnography and administration of Aboriginal affairs was broken. It was to be another two decades before South Australian Aborigines were actively encouraged to produce artefacts for sale, under George Taplin's administration at the Point MacLeay Mission.[34]

Angas's published account of his January 1844 expedition with Governor Grey refers to only two occasions on which he collected ethnographic items. Of the first Angas wrote: 'Mooloo, the native whom I met near the junction of the lake, parted with his mother's skull for a small piece of tobacco!'. This object was noted by William Cawthorne on Angas's return to Adelaide, shortly after Angas had drawn it for publication. Cawthorne described it incredulously as 'a human

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32 G. A. Robinson to C. W. Sievwright, 20 July, 1840, quoted in Lakic and Wrench (1994: 37).

33 G. A. Robinson to C. W. Sievwright, 18 July, 1840; 21 September, 1840, quoted in ibid: 36, 37.

34 One of the first indications that Point MacLeay Aborigines were producing artefacts for sale appears in the *Observer*, 4 February, 1860, p.6.

skull plastered up here and there with gum for a PITCHER. The natives put a string through one part of the skull ... and so carry their water. The skull is cleanish outside but very black on the inside. It looks a curious thing for a domestic utensil. They are as bad as Lord Byron'.[35]

On the second occasion Angas recorded without comment the requirement of reciprocity implicit in dealing with objects on the frontier of contact:

> about twenty young men and boys came up to us, and lighted their fires close to our encampment. Their hair was mostly in curls, and had it not been for the grease and ochre with which they had bedaubed their heads, many of them would have displayed beautiful hair. We obtained specimens of it, and they insisted upon having locks of ours in return, which they carefully stowed away in their rugs (Angas 1847a, vol.1: 94, 134).

It is unlikely that the Aborigines regarded this occurrence as extraordinary; their own use of human hair for hair-string would have provided a context.

Immediately prior to his appointment as Secretary to the Australian Museum in Sydney in 1853 Angas donated twenty-one artefacts to that institution. Several of these may have been Aboriginal, although it is likely that the bulk of this and other ethnographic donations made by him consisted of African and New Zealand artefacts (Specht 1980: 8–9). Angas returned to South Australia by the time of the Museum's foundation but by then he had abandoned his interest in ethnology for the scientific description of shells. He acted as temporary Curator of the Adelaide Museum during Waterhouse's absence on MacDouall Stuart's expedition of 1861–62 and assisted in describing the shells collected on that expedition (Gill 1886: 44).

Four small grinding stones 'from Southern Australia, carried by the females in a bag slung at their side' were presented by Grey to the British Museum during his term as Governor of South Australia, possibly as part of a larger collection.[36] Grey also shared the nineteenth-century collector's interest in burial customs and artefacts. During his January 1844 expedition to the colony's south-east he removed two mummified bodies from burial platforms near Lake Alexandrina, later sending them to the Royal College of Surgeons in London (*Adelaide Observer*, 6 April, 1844, p.5). The skull of a South Australian Aborigine, used as a drinking vessel, was collected by Grey and sent to Owen at the British Museum during the early 1840s; this may have been the very object mentioned by Cawthorne (Gill 1907–8: 232–33). Grey continued to correspond with South Australian linguistic workers after his departure from Adelaide, receiving a revised version of Teichelmann's Adelaide vocabulary as late as 1858.[37] As Governor of South Africa, Grey made presentations of copper ores and 'a collection of [mineral] specimens' to the Adelaide Museum in 1857, and donated a New Zealand greenstone axe thirty-five years later from his South African home (Hale 1956: 6–7).[38]

The departure of Eyre, Grey and Angas marked the close of the first phase of South Australian ethnographic activity. The period had been characterised by a remarkable level of linguistic research and publication. While the products of this research helped to make evident the differences between local Aboriginal groups, and highlighted something of the complexity of their social structures, the results barely touched the sensibilities of those European immigrants who rapidly outnumbered and displaced the diminishing Aboriginal population. Against the governing perceptions of Aboriginal people as undifferentiated, marginal and primitive, the work of the colony's early ethnographers seems more exceptional. In that light, the subsequent lack of attention towards the collection and description of Aboriginal material culture was hardly remarkable.

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[35] Cawthorne Diary, Saturday, 3 February, 1844. Foster (ed.) 1991: 32–33.

[36] Museum of Mankind specimen documentation no. 1840-12-1 (1–4), Jones 1985 ms. Grey's note also reads: 'The magnet is sensibly affected by them'. It is not certain that these were collected by Grey in South Australia. The 1840 date, if correct, may indicate that they were obtained on his first, brief trip to the colony, or that they were collected in Western Australia, which would be consistent with the description, 'Southern Australia'. Artefacts which Grey collected during his governorship in New Zealand were presented to the British Museum in 1854 (Braunholtz 1938: 7). Grey was also an enthusiastic natural history collector, with several species named after him. See Appendices C,D,E,F in Grey (1841a).

[37] Pers. comm. J. Simpson, 1991.

[38] On taking up his post as Governor of South Africa in 1855, Grey became a firm advocate of the South African Museum in Cape Town (founded in 1825). He sought copper ores from South Australia for it, in exchange for those sent to South Australia.

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A STAUNCH BUT TESTING FRIENDSHIP: DOUGLAS MAWSON AND T.W. EDGEWORTH DAVID.

BY D.W. CORBETT

Summary

CORBETT, D.W. (2000). Sir Douglas Mawson and Sir T.W. Edgeworth David enjoyed a long and fruitful friendship which began when Mawson was a student at the University of Sydney and continued until David's death in 1934. The relationship developed from that of teacher-student to expedition colleagues in the Antarctic and on to academic equals bonded by a passion for geology and the pursuit of scientific truth. Differences in character and temperament made the two men unlikely friends, but a strong bond of respect and affection enabled them to overcome the not infrequent tests of equanimity, particularly on Mawson's part. The connections they made and the influences they exerted across Australia in the days before air travel and e-mail mark an important phase in the development of a continental perspective on Australian geology and its emergence on the world stage.

A STAUNCH BUT TESTING FRIENDSHIP: DOUGLAS MAWSON AND T. W. EDGEWORTH DAVID.

D. W. CORBETT

CORBETT, D. W. 2000. A staunch but testing friendship: Douglas Mawson and T.W. Edgeworth David. *Records of the South Australian Museum* **33**(1): 49–70.

Sir Douglas Mawson and Sir T. W. Edgeworth David enjoyed a long and fruitful friendship which began when Mawson was a student at the University of Sydney and continued until David's death in 1934. The relationship developed from that of teacher-student to expedition colleagues in the Antarctic and on to academic equals bonded by a passion for geology and the pursuit of scientific truth. Differences in character and temperament made the two men unlikely friends, but a strong bond of respect and affection enabled them to overcome the not infrequent tests of equanimity, particularly on Mawson's part. The connections they made and the influences they exerted across Australia in the days before air travel and e-mail mark an important phase in the development of a continental perspective on Australian geology and its emergence on the world stage.

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T. W. Edgeworth David (1858–1934) was Australia's foremost geologist in the early decades of the twentieth century (Fig. 1). He was appointed Professor of Geology and Physical Geography at the University of Sydney in 1891 and his department was the first in Australia to train students for a professional career in geology. David was a gifted and dynamic teacher, an adventurous and energetic field worker and a prolific writer on geological themes, popular as well as scientific. His most ambitious project, a synthesis of the geology of Australia remained unfinished at his death in 1934. Aspects of David's life and achievements are covered in important reviews by Branagan (1973, 1981, 1985) and Carey (1990).

Douglas Mawson's long association with David began in 1899 when he entered the University of Sydney as a sixteen year old undergraduate. For the next thirty five years, until his death in 1934, David was in turn Mawson's teacher, mentor, colleague, confidant and friend. Their relationship was not always smooth, in part a measure of their age difference (twenty-four years), and their marked contrast in character. David was the quintessential Victorian gentleman, courteous, charming and erudite, wearing his heart on his sleeve and with a flair for publicity. Mawson although less outgoing was generous hearted with a friendly disposition, but inclined to reticence and introversion at times. Both were sensitive by nature, David particularly so, and at times this led to misunderstanding and over-reaction to real or imagined slights. Yet despite their differences, the friendship stood firm, surviving the hardships of Antarctic exploration, the upheavals of the First World War, and academic lives lived half a continent apart. It was a friendship sustained by regular contact at scientific meetings around Australia and David, an inveterate traveller, was a regular visitor to Mawson's home in Adelaide. Their correspondence, drawn upon freely in this paper, throws much light on the relationship between the two men. Unfortunately the surviving correspondence is markedly unbalanced, with few of Mawson's letters surviving in the David archive.

Mawson and the University of Sydney 1899–1905

Mawson began his studies at the University of Sydney as an engineering student. At that time the Engineering Department was part of the Faculty of Science and there were strong ties between Engineering and the newly established, and government supported, School of Mines. By Mawson's time the Geology Department was well housed and equipped and attracting a growing number of students, many of them, like Mawson, from Engineering; first year Geology being a compulsory subject for all engineering students. David himself was responsible for most of the

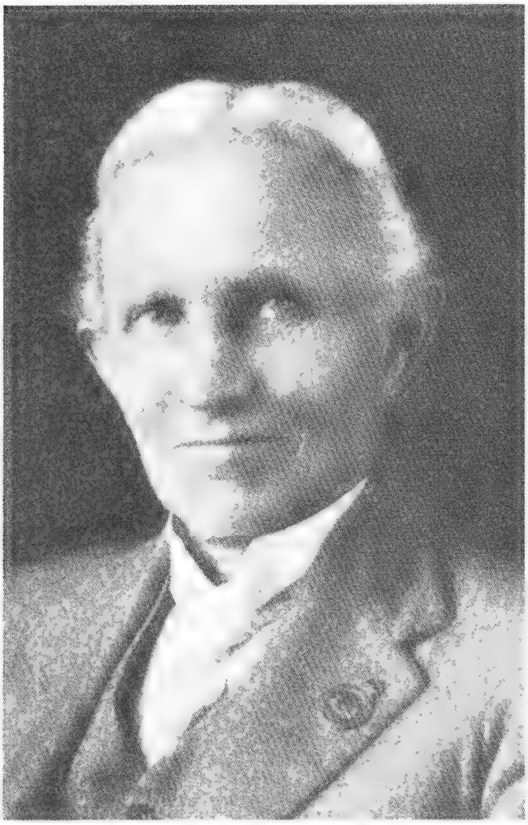


FIGURE 1. T. W. Edgeworth David, (1858–1934). (Photo: University of Adelaide.)

geology teaching with assistance in mineralogy and petrology from W. G. Woolnough (from his graduation in 1898 until 1901 when he moved to Adelaide) and H. S. Jevons (1901–05) (Branagan 1985: 129). Mineralogy courses, formerly part of Chemistry had been transferred to Geology with the re-organisation of the Geology Department so that Mawson in his early University years was exposed to a curriculum strong in geology, mineralogy and mining – all subjects which were to influence his later career.

David's wide-ranging interests and early experience, both in Britain and later with the New South Wales Geological Survey before joining the University, were reflected in his courses which covered physical and general geology and included lectures on Australian geology. Laboratory studies, both microscopic and chemical, were also introduced. Courses were strongly field-oriented, students being introduced to the pleasures of field work at an early stage of their careers.

One of David's prime interests was in the geological evidence for past glaciation. When he was a student at Oxford in the late 1870s the nature of glacial processes was still a new and hotly debated topic on which there was little general agreement. His first published papers (in the *Journal of the Cardiff Naturalists' Society*) were on the evidence for glaciation in South Wales and based on his own fieldwork. Subsequently, in 1887, when working for the New South Wales Geological Survey, he identified glacial sediments in the Permo-Carboniferous rocks of the Hunter Valley (David 1897), while in 1901 he confirmed the evidence for glacial action on Mount Kosciusko (David *et al.* 1901). In the same year, during Mawson's third year at the University, Walter Howchin, in South Australia, announced the discovery of glacial rocks of presumed Cambrian age in the Sturt Gorge south of Adelaide (Howchin 1901).

David had a strong interest in South Australian geology: he and Howchin had discovered the first Cambrian fossils in the Mount Lofty Ranges in 1896 (Howchin 1897). A Permo-Carboniferous age for the Hallett Cove and Inman Valley glacials having been established by this time (David & Howchin 1897), the recognition of two widely separated glacial events focussed attention on the significance of glaciation in the South Australian geological record, which was to have important implications for Mawson. Given David's strong interest in ancient glaciation it would surely have been a hot topic of discussion in the Sydney department and it seems likely that Mawson's own interest was kindled at this time. However his early enthusiasms were for mineralogy and petrology. He was awarded the Petrology Prize in 1901 and completed the coursework for his B.E. in Mining and Metallurgy in 1901. With David's support he was appointed Junior Demonstrator in Chemistry in 1902 and collaborated with T. H. Laby on a geochemical investigation of the radioactive properties of Australian minerals (Mawson & Laby 1904)

In 1903, on David's recommendation, Mawson took six months leave of absence to undertake a ship-based reconnaissance survey of the New Hebrides archipelago, a highly adventurous trip into a little known area. The expedition gave him valuable field experience under trying conditions and he proved himself a resourceful and perceptive field worker, qualities developed later in his career as an explorer and academic geologist (see Corbett

FIGURE 2. Douglas Mawson, (1882–1958).

1997: 110–112). His published report (Mawson 1905) was the first comprehensive account of the geology of the islands. Mawson's correspondence with David began on this trip and his enthusiasm and persistence are well shown in a letter from Tangoa on Santo (3 July 1903): '...have seen a good deal of S. Santo but have found no trace of any really old rocks'. He confides to David that he and his companion Harold Quaife deceived Captain Rason, the expedition commander, pretending to stay at a missionary's house knowing they would have been refused permission to climb the highest mountain on Santo. In the event conditions proved difficult and they did not reach the summit, but the geology was interesting and the mountain was found to be 'the ruined cone of an old volcano'. Mawson returned to Sydney in September 1903 to write his report and resume his research projects and coursework towards his B.Sc., which he completed, majoring in geology in 1904, graduating in 1905.

New Fields

In 1904, W. G. Woolnough resigned from the position of Lecturer in Mineralogy and Petrology at the University of Adelaide and returned to Sydney. With David's backing, Mawson applied for the position and was appointed, moving to Adelaide and taking up his duties early in 1905. David doubtless viewed the appointment of his former student to the Adelaide Department as a further strengthening of his ties with South Australian geology. His old friend Walter Howchin now became Mawson's lecturing colleague in the small Department. Differences in age, temperament and areas of interest allied to a strong perception that Howchin held a proprietary interest over much of South Australia led Mawson to choose a distant and relatively unknown area, the border country between South Australia and New South Wales in the Olary–Broken Hill region for fieldwork and research. It proved an astute choice; for it is a highly mineralised region of ancient crystalline rocks which provided abundant scope for his mineralogical and petrological interests (Mawson 1912). Among the numerous mineral occurrences was a recently discovered radioactive deposit which Mawson was the first to investigate fully and which he named Radium Hill. A new and complex mineral which he found there—a titanate of iron, uranium and rare earths—he named davidite after his former Professor (Mawson 1906).

Of particular significance in the Olary region, the igneous and metamorphic basement rocks are overlain by a sedimentary sequence of great antiquity which Mawson was able to relate to similar rocks closer to Adelaide, thus complementing some of Howchin's stratigraphic work in the Mount Lofty Ranges. It was his identification of thick glacial deposits within the sedimentary sequence which not only suggested correlation with the Sturt Tillite but re-kindled Mawson's interest in glacial rocks and processes leading to his first Antarctic adventure and the beginning of a lifelong concern with glaciation. That Mawson dated his involvement from that time is confirmed in a letter written to David many years later (25 June 1934), only two months before David's death, in which Mawson recalls a meeting in Adelaide with Dr. Caldenius, a European glacial geologist. Howchin was present at the time and evidently irritated Mawson, prompting the comment 'He [Howchin] does not appear fully to appreciate details of our older glacial series—as he talks of measuring up all the

FIGURE 3. Australasian Association for the Advancement of Science (AAAS) group photograph, Adelaide, January 1907. Included are David (front row, 11th from left), Mawson (back row, third from right), and Howchin (front row, 9th from left).

varve beds in the State—that job is more than a lifetime's work. I explained that I had been specially interested in these beds and regularly collecting data thereon since December 1906—and that it was my desire to better understand fluvioglacial sedimentation that caused me to seek a trip to the Antarctic with Shackleton'.

Mawson, perhaps prompted by David, seized the opportunity to meet Shackleton when he passed through Adelaide in January 1907 (see also Fig. 3). In the event his involvement in the expedition did not quite go the way he had planned, as he was to note later in his diary: 'In the first place, believing the Prof. [i.e. David] to be remaining in Antarctica for whole time, I asked only to go on voyage down—and that in 1909... Without any correspondence on subject the Prof wired me: appointed Physicist to Expedition and report at once. Now this is hardly what I wanted as, though I should have embraced the opportunity of stopping whole time as Geologist, I did not like the idea of physicist. However, after asking the advice of friends and now hearing from the Prof. that he and Cotton were only going down with the ship, I agreed to go... Now, when halfway to Antarctica, the Prof. decides to stay— he can do geology, I cannot' (Jacka & Jacka 1991: xxvii).

South with Shackleton

Despite Mawson's early misgivings about his role down south, David involved Mawson in the geological work from the start and the two shared quarters in the expedition's base hut at Cape Royds at the foot of Mount Erebus. When David convinced Shackleton that an attempt to make the first ascent of the mountain before winter set in would have scientific value as well as being a useful exploratory exercise, Mawson was included in the party which made the ascent. He was responsible for collecting geological samples as well as for the photographic work. It took the six man party three days and two nights of blizzard conditions to reach the rim of the old summit wall. David and Mawson with McKay then descended to the crater floor, and climbed the inner, active cone, looking down into the vent from which steam was rising accompanied by a loud hissing noise and periodic dull booms (Fig. 4). They calculated the height of the mountain to be 13 370 feet (4075m) above sea level.

The short but difficult journey yielded much interesting geological information (see David & Priestley 1914) and its success probably influenced Shackleton in selecting the same team of David, Mawson and McKay, designated the Northern Party, to undertake the journey to the South Magnetic Pole. There is a certain ambivalence in Shackleton's instructions to the party, for while the achievement of the Magnetic Pole is given first priority, the geological objectives are also stressed, including a survey of the coast of Victoria Land and the Western Mountains (Fig. 5), while on the return journey Mawson is given explicit instructions to investigate Dry Valley as a matter 'of supreme importance' and to prospect for minerals of economic value. Shackleton, most probably under David's influence, was now utilising Mawson for his geological skills, realising that the David-Mawson combination made a formidable team.

It was always going to be a tough assignment and there were tensions in the party from the beginning. Mawson was frequently frustrated and irritated by David's somewhat eccentric habits and behaviour and his physical inability to keep up with his younger colleagues, who consequently had to literally shoulder more of the burden of sledge hauling. There is no doubt that David did his best (he was then fifty years of age) and that he in fact overtaxed himself while carrying out his duties to the best of his ability, but the fact remained that his condition did place an enormous burden on his colleagues. While Mawson confined his frustrations to his diary and a rare verbal exchange, it appears that McKay was more directly abusive to his companion, reaching a point where he was prepared to certify David insane, and urging Mawson to take over the leadership of the party. It was a step Mawson was reluctant to take. While David at the end of their ordeal confided to Mawson that he had considered Mawson as leader from early in the expedition, in fact David (with McKay) had decided to push for the Magnetic Pole against the opinion of Mawson who was all for abandoning this to concentrate on the scientific objects of the journey (Jacka & Jacka 1991)

The Magnetic Pole journey was a gruelling adventure which could well have had a less satisfactory outcome. The three were perhaps fortunate to survive and there is no doubt that it was Mawson who held the small party together. Nevertheless, despite the difficulties, the two geologists were able to collect a considerable amount of geological information during the earlier part of the trip and Mawson is given due recognition in the final report (David & Priestley 1914). Perhaps most significantly, at no time during the entire expedition did Mawson lose his

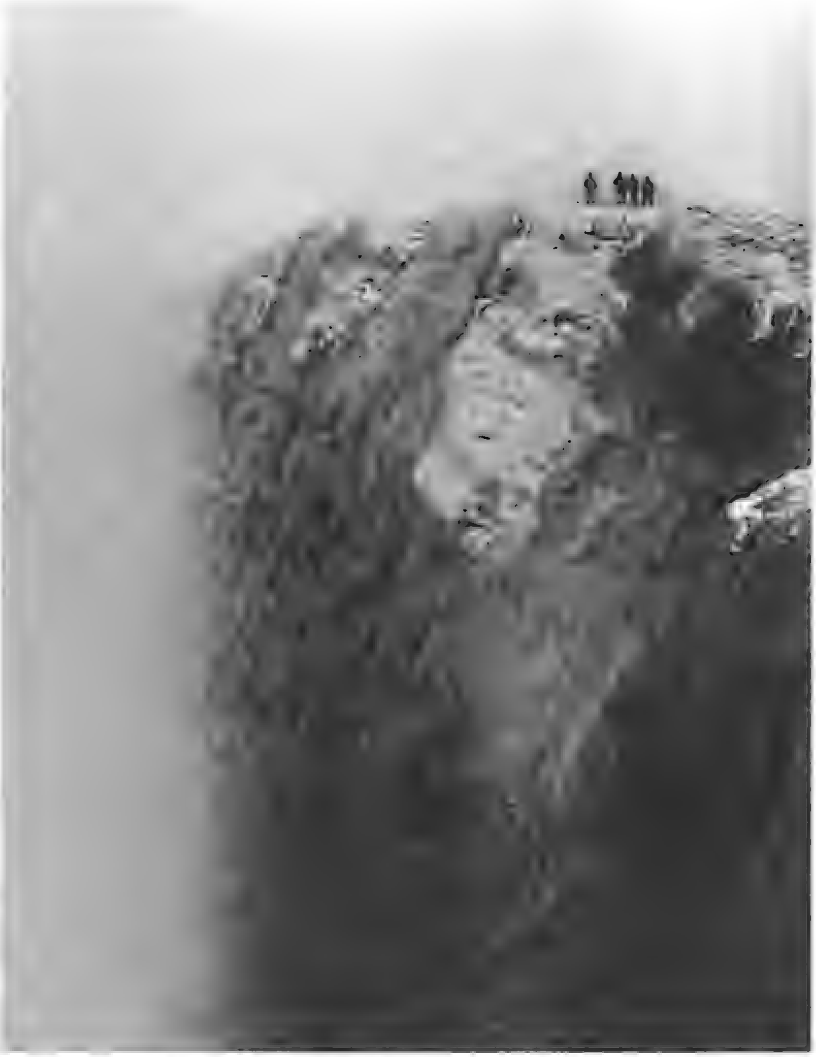


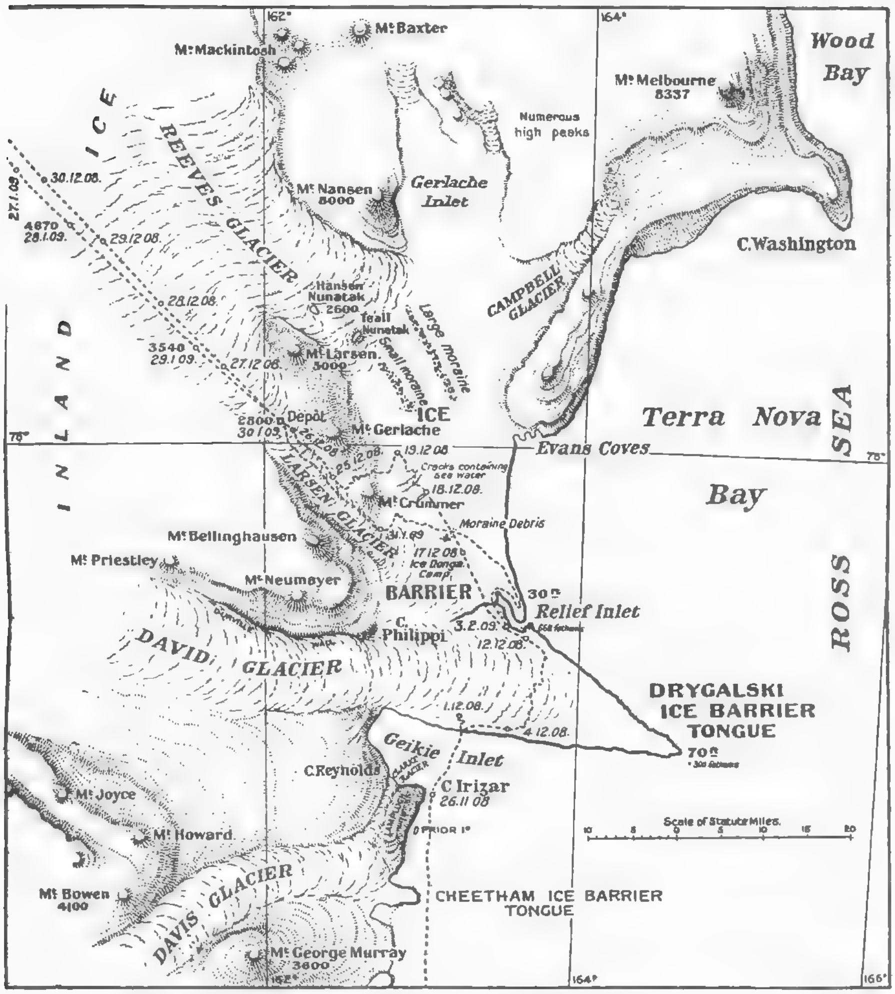
FIGURE 4 The active crater of Mount Erebus, taken from the lower part of the crater edge. (Photo: D. Mawson from David & Priestley 1914).

respect for the man who was dubbed 'The Prof.' by the expedition, and he was quick to recognise that, despite his idiosyncrasies, David always gave of his best and had the success of the expedition at heart. To Priestley, the other geologist on the expedition, David was 'a tower of strength' who was 'in spirit the youngest man in a very youthful company'.

The Stressful Years

Soon after the expedition returned to Australia, David wrote to Mawson (7 September 1909), discussing plans for the writing up of the results. David had all the geological specimens in Sydney and was relieved that Shackleton had not requested any to be sent to London. Mawson was to describe the southern journey rocks, and other likely contributors had to be found. Meanwhile Mawson still had to finish off his Olary-Broken Hill work but was already arranging leave of absence for a trip to Europe. For Mawson, the Shackleton Expedition marked the beginning of a lifelong involvement with Antarctica. For the next ten years the southern continent and the First World War were to occupy the greater part of his time while University matters of necessity

PLATE IX



Map of Nansen-Drygalski area of South Victoria Land showing Coast, Horst, outlet Glaciers, & Inland Ice.
Chiefly after Survey by Dr Mawson.

FIGURE 5. Map of part of the route taken by the South Magnetic Pole Party. (From David & Priestley 1914.)

assumed a subsidiary role. Before Mawson left on his Australasian Antarctic Expedition in late 1911, David wrote to him:

> My dear Old Mawson,
>
> Just a few words to bid you and all yours God Speed, and wish you all safe return. You have a great and perilous venture before you; may (you) be spared to come through it all unscathed and to return full of honour and gain to Science. My heart goes with you all. Ever my dear man, your affectionate old comrade.
>
> T. W. Edgeworth David.

The AAE expedition did indeed prove a perilous venture for Mawson and he was not to come through it unscathed, but it marked an important episode in Antarctic exploration with significant geographic and scientific results which established Mawson as an expedition leader of the first rank and a pioneer in the use of the new technology of radio. Mawson returned to Adelaide on 26 February 1914.

In a letter (15 November 1913) David, anticipating Mawson's earlier return, had written: 'There is so much to talk about that one hardly knows where to begin', and he 'eagerly awaits' details of Mawson's expedition, noting that 'the whole word has been intensely moved by the two great Antarctic tragedies' (i.e. that of the Scott party as well as Mawson's loss of Ninnis and Mertz). He was full of enthusiasm for the geographic and scientific discoveries made by the AAE, 'which have added King George V Land and Queen Mary Land to the map'; while 'there are all the biological, geological and glaciological results, your physical observations and the magnetic results, which should prove of the highest interest'.

Both Mawson and David volunteered for war service. David, though now 57 years old, was attached as an officer to a Mining Battalion and later as geologist attached to the General Headquarters of the British 1st Army. On the Western Front he was involved in drainage tunnelling and water-supply problems and trenches construction, and his expertise was recognised to the extent that he was appointed Chief Geologist of the British Armies (Carey 1990).

For Mawson, the war began before he had fully recovered from the traumatic and debilitating experiences of his expedition and while he was still extremely busy with post-expedition matters. After initial difficulties in securing a suitable position (MacLeod 1988), he spent two years in a highly responsible administrative post with the War Office in London during which time David and Mawson managed to keep up their correspondence. David was particularly concerned with the publication of the results of the BAE, writing to Mawson in London from the headquarters of the Australian Mining Corps in France (11 July 1916): 'It is very good of you to take on the work of seeing this Vol. II of Antarctic Geology when you are otherwise so busy. There is a lot of real good stuff in it, and it has been unfair to the authors to keep back so much good material from publication. It will be great relief to me when the vol., is published.' On 23 August he mentioned the 'nerve wearying work' and the strain of being 'more or less under fire about every other day, and I have had four months of it now, but am keeping very well, I am thankful to say'.

Mawson replied (17 September 1916) discussing BAE matters and criticising Shackleton, relations with whom had deteriorated after their return from the South and notably since Shackleton's ambivalence on plans for further explorations, which had resulted in Mawson taking charge and organising his own expedition. Mawson no longer trusted Shackleton and he confided to David that he had written to Lady Shackleton: 'to try and explain. I have stated that Sir Ernest upset some of the government officials in Australia with unwise policy. I stated finally that I myself was sad to see that Sir E. had dedicated the Geol Vol. of the 1907 expedition to Caird [the donor to his present Expedition] when Australia and Australians were the real contributors. A case of off with the old love and on with the new'.

On 13 October, David wrote to Mawson with unwelcome news. He had been inspecting a well on the Vimy Ridge when the windlass broke and he fell 80 feet to the bottom, sustaining severe internal and other injuries. Although he recovered well, the after-effects were to cause him trouble in later life. Nothing daunted, by 13 February 1917 he was once again writing of Antarctic matters, thanking Mawson for information on the progress of the AAE results—'your own scientific results seem to promise excellently'—as well as Vol. II of the Shackleton expedition geology—'good to hear that the latter is at last appearing thanks to your untiring unselfish efforts'. The volume, a compilation of individual contributions on aspects of Antarctic geology investigated by the BAE, includes one by Mawson on the petrology of rocks from the mainland of South Victoria Land (Mawson 1916).

Return to Academia

After the war, David and Mawson returned in 1919 on the same ship to Australia and to their respective Universities, but to very different futures. David was now approaching retirement while Mawson was about to resume his academic career after a very lengthy and stressful period away from the University. Little had changed during his absence: Walter Howchin was still active in the Department at the age of seventy four (although soon to retire), and facilities remained at a pre-war level. So when Mawson was appointed to the newly created position of Professor of Geology and Mineralogy in 1921, he had much work ahead of him to build what was virtually a new department. The question of adequate accommodation for teaching and research was not to be satisfactorily resolved for many years, and Mawson later regretted adopting a compromise solution which proved increasingly untenable as the years progressed. For most of the inter-war years his only full-time teaching colleague was Cecil Madigan, his Antarctic colleague for whom he had a high regard. Unfortunately, the two were too similar in temperament and ambition for them to be able to sustain a successful personal relationship.

Inevitably most of Mawson's energies in the early 1920s were taken up with the development of his new department, and it was to be some time before he was able to pick up the threads of research. David meanwhile was beginning to relinquish some of his academic responsibilities in Sydney, and to concentrate on his long-planned work—the compilation of a 'Geology of Australia'. The success of such an ambitious project depended heavily on the cooperation of his network of fellow geologists around the continent, a network he had worked long and assiduously to develop with great success. In Adelaide, Mawson, Howchin and L.K.Ward were important members—Howchin, as we have seen, since the 1890s. Mawson had hardly settled back into academic life before he received a letter (31 May 1919) in which David expressed a hope to see him soon and talk over a letter he had received from Charles Schuchert at Yale dealing with: '... the probable Proterozoic age of everything in SA that is below the Archaeocyathae, or at any rate below the Brighton Limestone—everything, that is, that is not Archaeozoic. There is much to support this view which was our old view until the discovery of Archaeocyathinae by Howchin and myself at Normanville'. While Mawson would scarcely have had the opportunity to put his mind to South Australian geology at this time, he replied to his old teacher (although his letter has not survived) for David wrote again on 27 July expressing his keenness in joining Mawson on a trip north and interest 'that you think certain bands in the purple shales are acid tuffs, or resemble acid tuffs. In my experience red beds are often the result of the weathering of tuffs'. There is no doubt that over the next few years there were times when Mawson came to resent the regular 'pestering' on geological matters to which David subjected him. Yet David was always solicitous of Mawson's health, the concerned friend and mentor interested in his work and offering support and encouragement—as the following extracts show.

On 21 January 1920 David replied to a (lost) letter of Mawson's in which he refers to Mawson's recent illness '[the] aftermath I fear of your really appalling experiences on your Adelie Land Expedition'. He continued: 'In regard to the comparative opportunities (to which you refer in your letter) on elaborating your work on Broken Hill as compared with the scientific work of your AAE there can't be the shadow of a doubt, I think, that you chose aright, and the scientific world will be greatly the richer through your expedition. I am glad you are going to apply yourself to study of the belt between Olary and Mt. Painter. It must be a fascinating region geologically and mineralogically'. He also refers to the agreement Mawson had recently signed with the New South Wales Government, which was to take over the printing of the AAE results: 'it will be a great load off your mind when the last volume is finished and in print.' And referring to departmental matters he wrote: 'It was high time that the Geological accommodation at Adelaide was improved. I am glad your authorities recognise the need at last.'

In June 1921 David visited South Australia and with Walter Howchin made an extensive trip north through Marree and Oodnadatta to Crown Point on the Finke River (Branagan 1981). The objective was to gather information for his 'Geology of Australia' as well as for the AAAS Glacial Committee. It was a good opportunity to catch up with Mawson again, and responding to an invitation he wrote (June 5 1921): 'I have promised also to stay with Howchin and Ward, but will come to you first.' He kept in touch while on his travels, writing from Marree of the train journey from Quorn 'in the lap of luxury' having been given the use of a private rail car 'fitted with bunks, parlour compartment, cooking stove and every luxury... From Quorn we have passed over extraordinarily interesting country, both geologically and botanically.'

David travelled extensively during 1921, visiting Western Australia, Queensland and Tasmania as well as parts of the northern and western areas of South Australia to gather information for his book. Back in Sydney towards the end of the year, on 22 December, he wrote a long letter to Mawson asking for information on South Australian geology and especially on the relative ages of the granites of which there were two phases; but were both Precambrian or was one younger? And was there any evidence of intrusion into the Archaeo limestones? The questions continued.

It was during 1921 that David revived interest in the possibility that fossil remains might be present in the Precambrian rocks of the Mount Lofty Ranges, an interest which dated back to investigations with Howchin twenty five years earlier. The new 'discoveries', in siliceous limestones below the Brighton Limestone at Reynella south of Adelaide, suggested crustacean remains and as David believed the horizon to be Upper Proterozoic (Precambrian), he was cautiously excited by the find: 'If the crustacean remains...are really, as I believe, Proterozoic in age it would be of quite extraordinary interest to secure a complete fossil specimen... There is... convenient to Adelaide, a considerable thickness of strata containing traces of obscure organisms, and it is to hoped that patient search by local geological workers will soon be rewarded...' (David 1922). David pursued the search with relentless vigour in the years ahead and was to tax the patience of Mawson at a particularly eventful period in his career.

Further Distractions

A more immediate development was precipitated at the end of 1924 by David's retirement as Professor of Geology at the University of Sydney (Branagan 1981, Corbett 1998). At the time Mawson was not fully committed to a future in South Australia despite his new responsibilities and he was keenly interested in the position, not least because of the advantages of being located in Sydney where the Government Printer had recently taken over the publication of the AAE results. He made enquiries regarding the terms of office from the Registrar in Sydney, to learn that David was strongly supporting his locum and deputy Leo Cotton. In deference to his former Professor, Mawson was slow to throw his cap in the ring. But as it transpired he almost won the chair, being the most favoured of a small group of candidates who were considered (including W. N. Benson from Otago and C. E. Tilley from Cambridge) and losing on the final vote 10–8 to Cotton. The complicated background to the appointment has been discussed by Branagan who concluded: 'There is little doubt that David swayed the Senate to ensure this appointment...[and] the Senate vote clearly was far from unanimous and some Professors were not happy with the procedures, and felt David was not as open as he might have been on the matter' (Branagan 1981: 38). Certainly to many it seemed that justice had not been done and Mawson was foremost among these, writing to David on the 23 January 1925. David replied promptly and at length justifying his role in events, and using all his charm and powers of persuasion to help pacify his aggrieved friend. He wrote (31 January, 1925):

> 'In spite of what is clear from your letter viz. that the judgment of our Senate in the matter of choice of my successor, guided as it was a good deal by myself, was in your opinion, one which did not do justice to yourself. You still sign yourself "ever yours sincerely"...Only a man of noble and generous nature could under the circumstances have done that and I know the words come from your heart. My own feeling is that nothing in the world should ever come between the friendship of you and me, and I am humbly thankful that your friendship for me has stood this tremendous test.'

He counters Mawson's queries and criticisms with his own views before conceding: 'Possibly my judgment and advice to the Senate has been at fault, but I am sure you know me well enough to be assured that if I have erred, it has not been through any motive other than a bona fide desire to do a fair thing.'

He concluded by taking the high ground and turning teacher: 'Have you tried to put yourself in Cotton's position, and imagined what you would have thought if you had run your Department at a University with conspicuous success for 6 years and then were asked to keep on for a 7th year, in order to stand down for someone else at the end of that time. Both you and I would, I think, have protested pretty vigorously—at least I know I would...we must please, agree to drop the subject. I want badly to write to you about your Antarctic matters and about S. Australian geology.'

David became concerned when Mawson did not reply to his letters and suspected that a Sydney colleague, H. S. Carslaw, Professor of Mathematics, who was also a correspondent of Mawson, had been causing trouble between them. On 17 March he wrote again: '[you have] probably been away somewhere in the Flinders Ranges and have not been getting your mail regularly' and continued 'you may have allowed the recent appointment to the Sydney Geology Chair to estrange us.' He refers to Carslaw as 'a notorious "sticky beak"' and concluded: 'If by any chance he has been making trouble between us, I would earnestly entreat you as one of my very dear friends...to tell me straight out what the trouble is.'

Two days later (19 March) David wrote again, still concerned but supporting Cotton, referring to his own disappointments (David had once, as a young man and before leaving England, sought a job in Canada), and pointing out:

> 'in your position in Adelaide, as far as research is concerned, you have one of the very choicest plums in the British Empire. What more glorious field for geological research could any one in the world have, with your special geological tastes, than the Mt. Lofty and Flinders Ranges. I can assure you, as a

> result of many years experience, that you would undoubtedly have had distinctly less opportunity for research at Sydney than you have at Adelaide.'

All this was very true but hardly likely, one would imagine, to pacify a resigned but still resentful Mawson. The letter ends on an emotional note: 'I realise that I am getting an old man now, and in the eventide of life one clings more than ever to early friends. It would be a bitter disappointment to me to lose your friendship now. I feel sure you will have the greatness and goodness to brush aside all feelings of resentment through disappointment, and will come back again into good fellowship, and will help me with my research in my old age, as you have helped me so often in the years that are gone.'

This letter drew a prompt double response from Mawson, for David wrote again on 1 April: 'Your kind letters have been an immense relief to my mind. I am most thankful that our old friendship stands firm. May it ever strengthen to one's life's end! I never perhaps fully realised what your friendship means to me until my experiences of the last four weeks. The first thing in the morning and the last thing at night you were in my thoughts and every mail I was eagerly looking for a letter from you. It was a great joy to me when it came at last.'

The Search for Ancient Fossils

David was particularly active later in 1925, travelling to Melbourne and Adelaide and on to Perth from where he intended to continue on to England. This extension of his travels was, however, postponed and he retraced his steps to Sydney. Although keen as always to see Mawson, David missed him on his way west (Mawson was in the field at Boolcoomata), while an invitation for a stopover on the return journey was declined. Nevertheless correspondence was kept up during these travels and David's letters were full of geological questions with enthusiastic references to the Cryptozoon fossils Mawson had found at Italowie and the question of their age (Mawson 1925). On 16 July, before leaving Sydney, David wrote : '[you] mention you consider the age Ordovician, is it really clear that the horizon is not Cambrian or even lower, such as the Adelaide Series?' And in response to Mawson's reply (missing) he wrote again on 9 August: '...glad to hear that you consider your Crytozoa from the Flinders Ranges at newest Cambrian, and probably Proterozoic'. He also 'hope[s] you will soon be publishing your work on the Boolcoomatta and Olary areas. It will be a very important contribution to our knowledge of Australian geology.' Later, on the train near Port Augusta on the way to Perth, he wrote again (25 August), musing on the similarity between the Italowie Cryptozoons and the algae from the Belt Series in Montana described by Walcott and adding: 'looks like strong confirmatory evidence of a Proterozoic age for the Adelaide Series.' He mentions his own finds in the believed Proterozoic rocks at Reynella and the '...hope now that you will be able to get some complete forms of those v. interesting small crustacea whose remains are so numerous, but so fragmentary in the Brighton Limestones.'

Before David left for England in late November 1925, he wrote twice to Mawson on the matter of the age of the cryptozoal limestones from Italowie, and their similarity to forms from the Macdonnell Ranges described by Ward (1925) and thought to be Ordovician in age. Very keen to clarify the matter, David wrote on 27 October: 'is for example their relation to the Adelaide Series established as by their relation to the tillites, the Brighton Limestone or the purple shale series?' Ten days later he wrote again trying to pin Mawson down on the stratigraphic position of the fossil-bearing beds.

By February 1926, David was in Cambridge writing to thank Mawson for papers received, touching on a range of matters and reviving the Cryptozoon question with a comment on the opinion of A. C. Seward (a leading palaeobotanist) which cast some doubt (later resolved) on the organic origin of the MacDonnell Ranges specimens. While David comments that his book 'progresses at a painfully slow rate', in a later letter (1 July) from London, he is again seeking Mawson's opinions, this time on Madigan's recently published work on Fleurieu Peninsula:

> 'Do you think it really proved that S. of Yankalilla – on towards Cape Jervis these limestones are really the equivalents of the Archaeocyathinae Lsts, or may they be equivalents of the Torrens etc limestones? Obviously if Madigan's views are correct, they considerably modify one's views about the dates of igneous intrusions in the Encounter Bay area. I cannot but think it probable that those pegmatised quartzites and conglomerates close to the rutile mine you showed us at Yankalilla are the basal beds of the Adelaide Series and the equivalents of the Aldgate basal beds'

David illustrated his letter with sketch sections and was grappling from half a world away with the interpretation of one of the key areas for the elucidation of early Australian stratigraphy. He admits that his 'path is beset with doubts and difficulties, and three months ago I had a rather nasty collapse from overwork, but am better now'

Mawson meanwhile, apart from his departmental responsibilities, remained very much involved with Antarctic matters, both past and future, to the extent that his own researches and David's probing questions on matters of local geology became a secondary consideration. He was himself overseas, in South Africa and England later in 1926, and carried out a short lecture tour in the United States, the proceeds of which were to help defray the cost of publishing some of the results from the Australasian Antarctic Expedition (AAE) which were still pending. He was also beginning to formulate plans for what were to be his own last Antarctic explorations, the BANZARE voyages of 1929–31, and in 1928 was back in England seeking support and a suitable expedition ship. (He was able to lease Scott's old ship 'Discovery' from the British Government for two seasons of exploration.)

While Mawson was away and pre-occupied with Antarctic matters, David, now back in Sydney, was still strongly focused on his self-imposed task of bringing together all that was known about Australian geology, well aware of the paucity of information in many areas and equally sensitive to the fact that time was against him—a truth which only served to heighten his zeal.

The Search Intensifies

Mawson was away again overseas in 1928 and in his absence David returned to South Australia and, possibly alerted by observations made by A. R. Alderman (D. F. Branagan, pers. comm.) made further finds of (he believed) organic remains in the Precambrian rocks of the Mount Lofty Ranges. The enthusiasm with which he renewed his forays into South Australian territory was reminiscent of his discoveries with Walter Howchin around the turn of the century. Then it had been a case of a professional working with a highly competent but unqualified amateur in what was virtually a 'terra incognita'. Now thirty years on, David's actions seemed very much like an intrusion into the preserve of a small but well-established geological community, headed by a long-time colleague and friend. Not surprisingly Mawson was perturbed, and his concern was compounded by the realisation (shared by most of those who became aware of the investigations) that David had been so carried away in his enthusiasm that he had begun to lose touch with reality.

The saga began on 26 September 1928, when David wrote a very long letter to Mawson, in London at the time, telling of his discovery of fossils,which he believed to be eurypterids, in the old Beaumont quarries and also at Tea Tree Gully. The finds were 'of immense scientific importance' and he was preparing a paper for the Royal Society (David 1928). David wrote enthusiastically that 'more specimens will be of quite extraordinary palaeontological and evolutionary interest.' He also mentioned that A. R. Alderman, one of Mawson's staff, had assisted with the collecting.

Impatient that he had received no response from Mawson on the matter of the fossils, David wrote again on 9 October in a state of high excitement:

> 'To my mind the whole thing is stupendous. Some 5000 feet [1524 metres] (more or less) of strata from just above the Blue Metal Limestone down and halfway between the upper and lower Torrens Limestone contain remains of Eurypterids of great variety and in great abundance certainly on some horizons, as for example in that of the 2 ft. [60 cm] bed of quartzite at Tea Tree Gully. If only I could be with you even for a few hours I'm sure I could fill you with enthusiasm for the whole matter... It will be for you and your Geology School to enter this 'promised land'. One cannot be thankful enough that one's eyes have at last been blessed with the sight of it after some 35 years of intermittent seeking... Of course it [will] take a hundred years or more to get a fairly complete acquaintance with the Adelaide Series Fauna, but it should be quite possible in a years time to collect sufficient eurypterid material to warrant publishing a detailed description'

A Friendship Strained

Mawson while in England had heard independently of David's activities in South Australia and returning to Australia n the SS *Mooltan* he wrote on 26 September:

> 'Your letter re fossils in the Adelaide Series, near Adelaide is interesting. I have, of course, poorly indicated fossil remains from elsewhere in South Australia. Further examination of these has been held up until I can complete my section in the North Flinders Range. I got some money for expenses for this voted by the University Council late last year, and if this present matter [proposed Antarctic

expedition] had not cropped up would have been there now. The 'pellets' in the shales associated with the archaeocyathinae at Sellick's Hill, were left to you by agreement as you had first drawn attention to them. When I left Australia in March, I asked Madigan to write and ascertain whether you intended to go on with them—if not he was to examine them and the enclosing rocks for fossils... I gather from your letter and a reference made in a letter from Madigan that you examined other rock formations of the Adelaide Series and found abundant traces of life.'

'I am wondering what you are including in your operations in South Australia. I have clearly explained to you by references on several occasions both verbally and by letter, that for years past I have had a plan of campaign laid for the eventual elucidation of the stratigraphy of the older rocks of South Australia and it has been going forward according to plan. To that end I have encouraged and trained various students—and allocated to them and to Madigan problems which have been selected as part of the scheme for the ultimate complete unraveling of the stratigraphy. I have spent money in travel to see formations in South Africa and America and familiarise myself with glacial petrography and the character of the fossil forms of the plant and animal life of the oldest terraines.'

'This problem I particularly decided upon as a major life work after I found I was not wanted in Sydney for the Chair there. I am not looking for the limelight consequently have not published anything but adventitious scraps of the knowledge of the said rocks now accumulated. My plan has been to publish little until'...(here the letter ends with the remaining page(s) missing).

It was a strong letter and the tenor of it was not lost on David; but his reply on 18 October was entirely in character, beginning with an admonition of Mawson for not replying to his earlier letters and going on to feign surprise, hurt and indignation when it appears 'I have, most unintentionally, given you offense', and 'that there is a suggestion implied though not expressed in so many words, that I have been doing things behind your back, and have in some measure been jumping your claim. If any implication of this kind is intended, I wish to state most emphatically that it is most deplorable that you should entertain any such idea...'

He then embarks on a lengthy review and justification of his work in South Australia, dating from his early associations with Tate and Howchin and his publications in the Transactions of the Royal Society. He refers to the results of his Reynella discoveries (David 1922), when 'You certainly never gave one the slightest hint at the time that you in any way resented my publishing this paper'; and he reminds Mawson that the two of them collected together at Brighton and Reynella in 1925 'with the expressly affirmed object of trying to discover further and more definitive traces of life in the rocks of the Adelaide Series. Again you did not give me the least hint that you did not wish me to proceed with the work, and you most kindly and generously helped me along with the work of collecting.'

While Mawson was away earlier in the year David had concluded from his microscopic studies that the Reynella rocks 'were not only swarming with small fossil organisms, but that even their branchidae, tentacles etc. were beautifully preserved. This find greatly thrilled me and I wrote over at once to Howchin, Ward and Madigan about it and followed on myself. Had you been there of course, I would have gone to you first and no possible misunderstanding could have arisen.'

David was so carried away with enthusiasm for his discoveries and his desire to prove their authenticity that he labours the point of the frequency of his visits to Adelaide, the practical help he received from Mawson's own staff (Madigan, Alderman and Brock) as well as Howchin; and the details of the search. Perhaps part conscious of the effect this would have on Mawson he continues:

'I sincerely trust that if you have had the goodness to read this lengthy letter so far, you will realise that I was in no way prepared to find that you in the least resented your old teacher and colleague having ended his own intermittent search for fossils in the Adelaide Series by coming upon forms which for variety and structure have simply taken one's breath away... When you see one's paper in print (I hope it will be ready now in 2 or 3 weeks) I feel sure that there is nothing in the paper of which you will disapprove. One has, I hope, quoted fully and fairly your own work on the Adelaide Series in that paper. The occurrence of this fossil fauna so widely distributed throughout the Adelaide Series is a really stupendous thing teeming with possibilities, and the surface of the problem has as yet been barely scratched. It will be for you and your staff and students surely to enter into the Promised Land, and I'm sure that a grand future a really tremendous future lies before you there.' Finally he wrote:

'I am convinced that you must have written that letter to me of 29.9.28 [David has the date wrong here. He is referring to the 'Mooltan' letter of 26.9.28] under some misapprehension. Of course it is not nice for any scientist (such is human nature alas! I confess guilty to the weakness myself) to have some other scientist come along and discover a gold reef under one's front door step—personally I

FIGURE 6. Edgeworth David at the Tea Tree Gully 'fossil' site excavation, with workmen, 1930. (Photo: E. Joyce.)

don't like that sort of thing at all, and it has several times happened to me—but in your case while your feelings would be I'm sure like mine—viz. regret that one hadn't found it all out oneself—you are surely far too big a man, a world personage for all time, whose Antarctic volumes are already making a very creditable show alongside of the Challenger expedition Reports, to resent your old Professor finding after many years the bread he has cast upon the waters!'

'Your "Mooltan" letter, in the light of your non-reply to my friendly letters has caused me very much pain. It is not in the interests of our friendship or of Science. Please may I, only with the best possible intentions and friendly feeling, be allowed to return it to you? I trust...that you will kindly say yes.

Yours Very Sincerely
T. W. Edgeworth David'

This letter has been quoted at length because of the way it illuminates David's character and the nature of his relationship with Mawson. He cannot resist resorting to the ploy of one-upmanship—the old Professor scoring a point off his old student and having taken the prize, to magnanimously hand it over to his worthy pupil and successor. Although highly sensitive himself and conscious of the fact that Mawson might have been disconcerted by the news of the discoveries, he seems peculiarly insensitive in the manner of his writing. He was so overjoyed with what he believed to be the high point of his career that he could not understand others not being equally excited and responding quickly and with enthusiasm. That Mawson, whose opinion and counsel he valued so highly, did not do so was devastating and David could not hide his feelings or control his pen. Mawson could perhaps have acknowledged the flurry of letters he received more promptly, but he was very busy in London on Antarctic matters and his response, when it came in the 'Mooltan' letter, was entirely in character—courteous and cautious while expressing a sense of affront that was entirely justified.

But David was now a man obsessed, and with no further word from Mawson, he wrote again on 28 October:

'I am deeply distressed at not having any reply from you to my last three letters. You are one of my students of whom I am especially proud; and for whom I have a warm and abiding affection, which nothing can alter, and your present silence is so distressing to me just by reason of the affection I have for you. Were it not for this I would just have said "Well if he won't reply to my courteous letters written with the simple desire to remove any possible misunderstanding, why not let him rip!"

He then, mentions his indebtedness to Howchin during his recent researches, commenting: '... for with all his faults—and I wish I had as few as he—he really is a wonderful old man and has done a monumental piece of work around Adelaide and far beyond.'

On 1 November, 1928, Mawson finally put David's mind at rest writing with apologies for not replying earlier and explaining that he had been extremely busy but

'Now I am beginning to breathe again lectures are over. Alas! I am sorry to have worried you but I have merely accumulated letters from friends whose handwriting I know until the moment should arrive when I could deal with them... Yours of course are of the greatest interest. Since arriving back I have of course heard of course what your discoveries and work over here has been—and your letter of 26th September is most interesting. From reports in the English papers it was not at all clear what you had discovered. Though it did indicate that we in Adelaide had been sleeping on the most stupendous museum of clearly preserved fossils…'

(The page ends here and the remainder of the letter is missing). Courteous and cool in its introduction, the letter was beginning to warm up a little. But there was certainly no stopping David in his quest. He returned to Adelaide several times over the next few years, in 1929, 1930 and 1933, to investigate the Tea Tree Gully quarry.

Standing Firm

Mawson remained aloof and did not become seriously involved, but the fact that David was regularly assisted by members of Mawson's department, staff and students, indicates a desire to keep an eye on proceedings. David was assisted by Madigan and Alderman in 1929, by Rudd in 1930 (Fig. 6), and on his last visit in 1933 when he also visited the Beaumont Quarry, by Madigan, Kleeman and Barnes. On this, his last visit to Adelaide, he spent time with Madigan at the University looking over material from Central Australia including large masses of cryptozoa which he found 'very wonderful'. In September 1929, Mawson supported David and his collaborator, R. J. Tillyard, in seeking a grant of £100 from the Royal Society of London to open up a quarry in the Precambrian rocks near Adelaide to search for further fossils. The successful outcome enabled David to carry on his research. Mawson was asked to contribute a piece on evidence for the Precambrian age of the Adelaide Series and for an unconformity below the fossiliferous Cambrian in the Flinders Ranges for: 'a joint paper by Tillyard, yourself and myself for the Phil. Trans., which would be a nice little "quid pro quo" for the 100 quids for which we jointly applied'. He tries again to win Mawson's enthusiasm, noting that Tillyard is '...quite definite as to the arthropod nature of the Teatree Gully fossil', a photograph and a drawing of which he includes. Mawson was not to be tempted, however, and in a cool letter (18 September 1930) he offered to run out for a couple of hours to Beaumont but 'My time, however, is extraordinarily full'. He also declines to collaborate on the proposed paper writing : 'I would not enter into a new subject without going very fully into it', while he has half a dozen papers on the verge of publication.

By the middle of 1931, with the BANZARE cruises behind him and the pressure off a little, Mawson was able to catch up with his correspondence. On 2 July he told David of Kerr-Grant's discovery of the Karoonda meteorite and the public interest aroused; most reported finds were 'myths' but one report had led to the visit by Alderman to the previously unknown Henbury meteorite craters and the collection of numerous iron meteorites. On 14 July he wrote again telling of Madigan's recent seven week trek east of Alice Springs and his discovery of archaeocyathae in the same relations to the algal limestones that Mawson himself had found in the Flinders in 1929. While David was worried by ill health and his old war injuries during 1931, he was buoyed by the publication of his geological map of Australia and by the renewed and more regular contact with his old friend. By 12 September he was optimistic enough to approach Mawson again regarding the Precambrian fossils. He wrote:

> 'Anxious that you should join me in a stratigraphical note on the horizon of those fossils in the quartzite at Teatree Gully. You remember that Tillyard and you and I joined in an application to the Royal Society London for that grant of £100. The results have exceeded even sanguine expectations, and Tillyard has prepared a very able paper on the most typical of those protoarachnoids. We have a specimen nearly perfect about 6 inches long. I should personally be extremely grateful if you would help me with this stratigraphical note. If you will say yes! I will forward at once some rough ideas of my own for you to trim up.'

Mawson did not say yes. In his reply of 23 September he quite firmly distanced himself from the Teatree Gully project:

> 'With regard to the fossil evidence you must rely on your own judgment and that of Dr Tillyard. With regard to the stratigraphical position of those beds, Howchin is, I suppose, the best authority. In view of the fact that Howchin has made a special feature of the study of the old sedimentary rocks in the neighborhood of Adelaide, I have never entered the field in any critical fashion and have reserved my efforts for more distant regions. Should Howchin pass away, I would, of course, feel it my duty to re-investigate the Adelaide region. Until then there is such a wide field in this State for further work that one feels one would do better for Geology as a whole by extending observations elsewhere rather than critically examining a field that has been given very great attention by Howchin.'

A Shift in the Relationship

David's last attempt to gain Mawson's support had failed; indeed it had merely provoked him, arousing all the old resentment about Howchin's monopoly on the geology of the Adelaide region. As far as Mawson was concerned the matter was now closed, and in his firm and calculated withdrawal from the field it seems that in the twilight of David's life, roles had been reversed: Mawson is now the mentor and David the receiver of counsel. While David continued to keep Mawson informed on the development of the Precambrian fossils saga, Mawson's letters focused on other topics including Madigan's work in the MacDonnell Ranges and Hossfeld's in the North Mount Lofty Ranges. Nevertheless David missed no opportunity to raise the question of the possibility of finding Precambrian fossils in the Flinders and Central Australia where the rocks were less altered, while he diplomatically kept away from mentioning the Adelaide fossils.

Meanwhile David had written to geologists world-wide, spreading the news of his discoveries. Mawson's skepticism regarding the Precambrian fossils was shared by many in the geological community, including J. W. Gregory (Glasgow University), C. E. Resser (Smithsonian Institution), and Calman and W. D. Lang, biologist and geologist respectively at the British Museum, and Woolnough at home. Lang was 'sorry not to be able to go as far as you in considering these supposed organisms referable to annelids or arthropods. I cannot deny that they may be organic, though even this I think rather unlikely than probable'. The general feeling was that the impressions were, as Woolnough put it, 'mere concretions'; but with Tillyard now an enthusiastic convert (as well as an expert on living

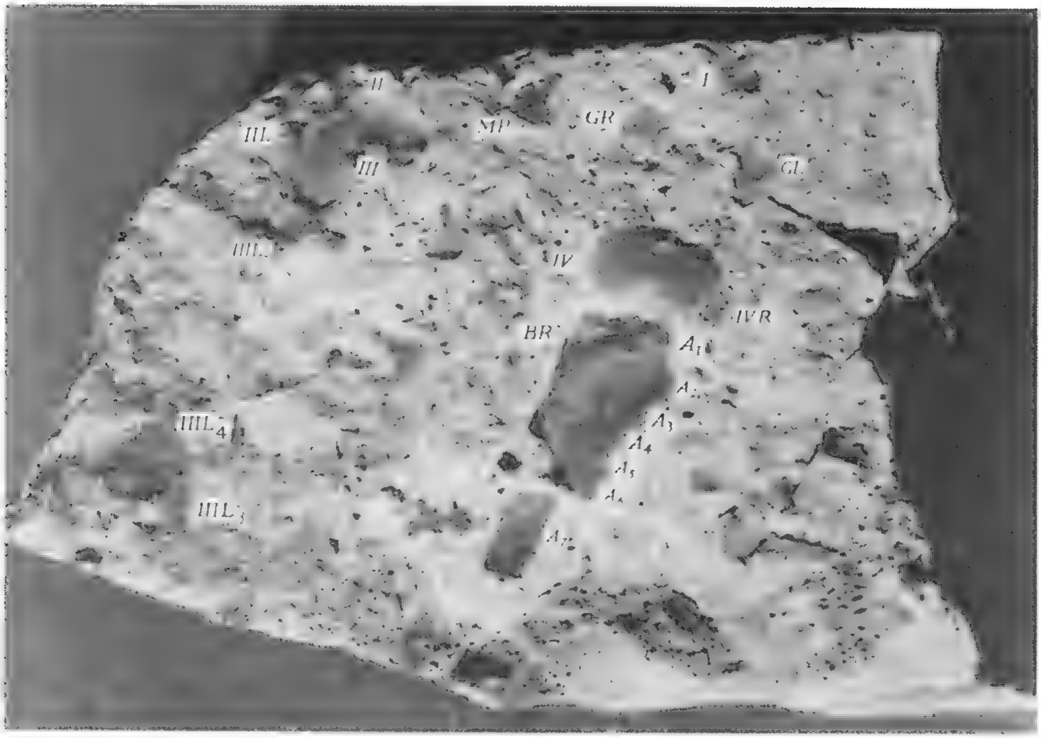


FIGURE 7. The supposed Precambrian fossil *Protadelaidea howchini*. (From David & Tillyard 1936: plate I. Angus & Robertson.)

arthropods) and cautious and non-committed support from some of his correspondents overseas, David pressed on. Tillyard remained less confident than David of gaining acceptance for their work, and sounded a warning in a letter (5 February 1932) referring to some of Calman's criticisms and continuing: 'In science, as elsewhere, nobody is to be allowed to run beyond the pre-conceived limits set by the conservative opinion of his own times. So, I much fear, you and I are in for a severe castigation when our paper comes out. Nevertheless, when we are dead, complete fossils of the same Pre-Cambrian age will be brought to light, and will to a large extent justify the reconstruction which we have given'

The paper referred to was rejected by the Royal Society of London in July 1932. Tillyard meanwhile, in a letter of 7 September 1932, was concerned about the fate of specimens sent over to the British Museum in the light of the rejection of the paper by the Royal Society. While the Society would 'return the typescript and the drawings..., these are of little value without the type fossils'. He was also concerned about Mawson, and wrote: 'I am very sanguine as to Mawson's reaction; do not forget the old complex about your working in his field. He is a very nice fellow and is always very decent to me, but I wonder whether he has a big enough mind to see your point of view in this particular case.' Tillyard was also keen that another application be made for a research grant from the Royal Society. Mawson had been an influential supporter who had helped secure the initial grant, but this time Tillyard is less than confident, writing: 'As he [Mawson] is going to London next month, I should expect that he would be more inclined to secure a grant for exploration in the Flinders or MacDonnell Ranges.' Ten days later Tillyard was able to report that the specimens were to be returned and the scientific fraternity were a little less antagonistic. 'Perhaps they now feel rather ashamed of having turned us down, and are trying to make amends'. Tillyard, still hopeful of enlisting Mawson's support, wrote to David (22 October 1932) 'I do hope you will bring Mawson round to our way of thinking'

David was still trying. On 2 September he had written to Mawson with the Royal Society paper rejection fresh in his mind and sending copies of the referees' reports (by Calman and Lang of the British Museum) with his own critical asides. He

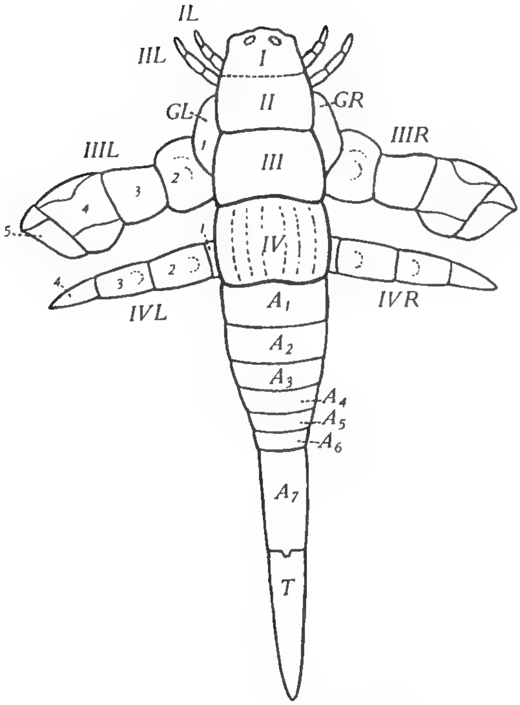


FIGURE 8. Reconstruction of *Protadelaidea howchini*, dorsal view. (From David & Tillyard 1936: plate IX. Angus & Robertson.)

clearly did not accept the judges verdict and had found some of the comments offensive. Calman, 'a mere zoologist' had concluded his report : 'with great reluctance I have come to the conclusion that from a zoological point of view this paper is entirely without scientific value.' Lang's criticisms, 'though not rude like Calman's... [are] not brought forward at all... if only he had read our paper carefully... His criticisms really in no way weaken our position.' David then appealed to Mawson: 'Unwilling as I am to trespass on your time, which I know is so very fully occupied, I wish you to kindly do me the favour of reading through these notes on the Adelaide fossils very carefully, if you will be so good. With the arthritis becoming constantly more acute... one realises alas! that that little bit of work at Teatree Gully may be the last bit of field work of one's lifetime and which embodies the only discovery of any consequence that I have ever made, I am naturally anxious to see a reasonably good foundation laid.'

On 6 September he wrote again with further descriptions of the fossils and concluded '...in our opinion, the evidence for the organic origin of these fossils is so conclusive as to be quite overwhelming.' A postscript hammered home the point:

> 'The Teatree Gully quartzite has already yielded so many remarkable and entirely new forms of pre-Cambrian animal life that in my opinion its further exploitation in the way of quarrying and splitting the blocks parallel to the cleavage is really of enormous palaeontological importance. No other strata of such an age anywhere in the world, have yielded results in the least comparable with this. Surely before trying out new areas in the northern Flinders or the Macdonnells further work should be done at Teatree Gully e.g. the discovery of a third specimen of Protadelaidea howchini [Figs 7–8] would surely satisfy even the British Museum brahmans...'

On the 15 September he wrote advocating further quarrying at Teatree Gully, adding 'I would immensely like to hobble over the ground (while I can still hobble) in your company some time before you leave for England.' Included in this letter is an annotated section from his own paper (David 1928), indicating the position of the supposed fossil bearing-beds (Fig. 9).

Mawson never made that visit with David, for he left for England towards the end of 1932 and did not return until July 1933. Before leaving however, he forwarded to the Royal Society in London, at David's request, an application for a further grant for the excavation of the fossil site. Despite David's continuing hope for unqualified support, Mawson's attitude was at once diplomatic, uncompromising, yet supportive. He appended the following statement: '[as the] wording on the document does not properly express my views, I am merely forwarding this supporting note... The position is that Sir Edgeworth David is still convinced that certain markings, impressions and cavities in a thin bed...of ?middle Proterozoic age are of organic origin. My view is that some of them are difficult to account [for] on a purely inorganic basis, but I see nothing indisputably organic in them'. His conclusion was pure diplomacy. 'If they are organic their occurrence is of great importance.' He supports the further grant to prove or disprove the "fossils" and would like to see the matter further investigated.

Disappointed to learn that Mawson had not approved of the wording of the Royal Society application (he claimed he thought that Mawson had accepted *Protadelaidea*), but still undaunted, he returned to South Australia in April 1933, while Mawson was away, on what was to be his last visit. On this occasion he was assisted by Madigan, Kleeman and Barnes in the field and stayed at Mawson's home.

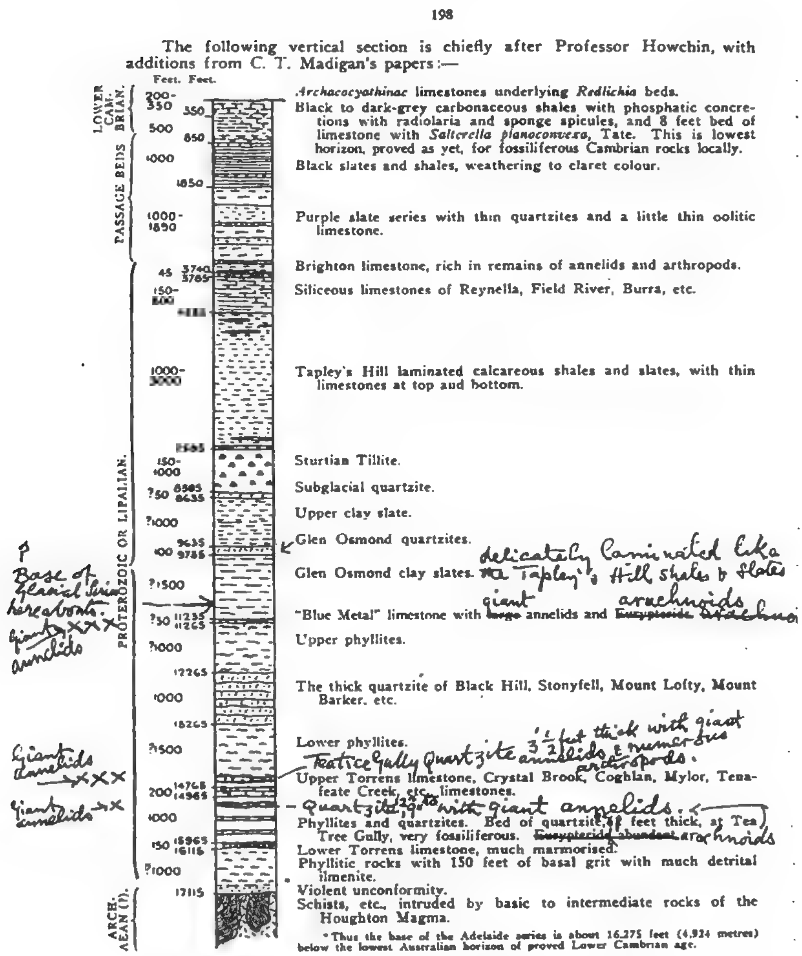


FIGURE 9. Annotated geological section (from David 1928), showing position of supposed fossil-bearing formations in the Precambrian Adelaide Series. This was included in a letter from David to Mawson, 15 September, 1932.

Envoi

By the end of 1933, David's health was giving serious cause for concern but his letters to Mawson on a range of geological matters continued unabated. He wrote in December 1933: 'My health has been v. poor lately and my suffering from my old war injuries has been increasing but I am thankful to say that there is some "life in the old dog yet" and I may yet live to be of some service to my very distinguished old student for whom I cherish no small affection.' In March 1934 he was writing of Antarctic matters, Mawson's work on coorongite in the South East and north Flinders Ranges geology. He also had plans to visit his publisher Edward Arnold in England for discussions on the still uncompleted 'Geology of Australia'. Meanwhile work on the book was continuing, though very slowly, with the help of W. R. Browne and other Sydney University geologists. By July the trip to England had been deferred to the end of the year. In a letter of reply to one of Mawson dealing with glacial matters on July 11, his old student was asked about his two Precambrian glaciations with the question: 'Have you, please, published anything about this?', while his last letter to Mawson (15 August 1934) was concerned with the Henbury meteorite crater reserve.

David did not live to complete his book. He died in Sydney on 28 August 1934 and W. R. Browne eventually saw it through to publication. This proved a monumental assignment as David had been continually re-organising his material and the book lacked a final plan. Also as the project had been in progress for so long, not the least of Browne's tasks was to bring the information up to date. 'The Geology of the Commonwealth of Australia' in three volumes was published by Edward Arnold in 1950, edited and much supplemented by Browne. As Branagan has written: 'Browne had to write David's "Geology"—and he did it magnificently' (Branagan 1981: 52).

Lady David began compiling a biography of Sir Edgeworth after his death but her draft had been rejected by Angus and Robertson. This was a severe blow, and her daughter now set about rewriting the manuscript before taking it off to seek a publisher. She wrote to Mawson on 27 March 1936: 'I have put in 18 months severe work and amassed facts only about him—but he had such a romantic life it is not easy for me to "see the wood for the trees".' She concluded: 'I am so glad you loved him.'

Mawson felt the loss of his old professor keenly and when asked by the Royal Society of London to write an obituary he did so in prose that was very high in its praise, not only of David's scientific achievements, but of his character and personality. He wrote :

> 'Attributes of his greatness were an endearing charm of manner and a nobility of mind embodying high Christian principles. He was an accomplished scholar plentifully endowed with fine instinct and broad vision... With a rare fund of anecdote and a keen sense of humour, as well as a vivid dramatic appeal and exceptional powers of narration, he was always good company and the centre of attraction in any gathering. By tact, influence, and a unique personality, he promoted science, and especially geological research, in Australia, for more than four decades.'

And with reference to David's geological achievements: 'Next in interest to the investigation of evidences of past glacial climates in the Australian geological record, the subject which claimed David's special attention during the later years of his life, was that of search for fossil evidences for life in the Pre-Cambrian terrains of the neighborhood of Adelaide. In what appears to be the upper limit of the local Pre-Cambrian sediments, he, some years ago, recorded impressions of a fragmentary nature which he determined as relics of crustacean life. He more recently came upon coarser and still more obscure impressions at a much lower horizon; these, also, he believed to be fragments of crustacean or proto-crustacean life...he was still investigating this fascinating problem at the time of his death.' (Mawson 1935).

The abundant material that David had left on the supposed fossils, was, at Lady David's request, organised by W. R. Browne and Leo Cotton and, in cooperation with Tillyard, published in book form by Angus and Robertson (David & Tillyard 1936).

Precambrian Fossils – the Sequel

With David no longer there to practise his persuasive advocacy for the Precambrian fossils, the memoir did nothing to revive interest and there were few geologists in the years ahead who were prepared to keep an open mind on the subject. Fifty years on, S. Warren Carey, who had seen some of the original specimens, was a powerful spokesperson for the skeptics. He wrote: 'I don't know any palaeontologist today who accepts them as organic remains, and little is said about them, as though this skeleton in David's cupboard is best forgotten' (Carey 1990: 46). But over the years between they had not been entirely forgotten. Even if David was wrong, palaeontologists since his day have recognised that the relatively complex animals found as fossils in the earliest Palaeozoic rocks must have had Precambrian ancestors. In the mid-1950s, a highly respected textbook of invertebrate palaeontology made the point clearly: 'The Phylum Arthropoda comprises an unusually large and varied group of highly developed invertebrates whose clearly long and extensive history reaches back almost certainly into the Pre-Cambrian' (Shrock and Twenhofel 1953: 536), and although they do not discuss David's discoveries, his Memoir is listed in their bibliography.

If David's fossils were indeed 'mere concretions', how could such an accomplished scientist (and his specialist collaborator) have made such a misinterpretation? Carey asks the question and proffers a possible answer; perhaps: 'David, working through so many thousands of specimens, may have progressively filtered out those with bilateral symmetry, and Tillyard, working with such a biased set, could easily have been convinced that they had to be organic' (Carey 1990: 46).

On home ground in South Australia, David's torch had been kept burning since the late 1930s when a young geologist appeared, who carried many of David's characteristics, notably enthusiasm, flair and imagination. R. C. (Reg) Sprigg stood in the same relationship to Mawson as Mawson had to David four decades earlier. As a student he found what he thought were arthropod remains in rocks close to the Precambrian–Cambrian boundary at Sellicks Hill south of Adelaide. Mawson was singularly unimpressed and later, much to Sprigg's chagrin, had the key specimen thrown away (Sprigg 1989: 95). But within a few years serendipity took a hand, and Sprigg, working for the South Australian Department of Mines on a field mapping project in the Ediacara Hills west of the main Flinders Ranges, found a fossil jellyfish in rocks at that time believed to be lowermost Cambrian. Mawson, perhaps inevitably, was not initially convinced, and there was a strong skeptical element in the geological fraternity regarding the validity of Sprigg's discovery. However, further finds by Sprigg and other collectors, of more jellyfish as well as numerous other undoubtedly animal fossils, with a wide range of forms and some with problematical affinities, became world famous as the Ediacara Fauna—the earliest animal fossils known in the geological record. In his final years Mawson was a strong supporter of the investigation of the Ediacara fossils and on-going research was carried out in his old department after his death by Martin Glaessner and Mary Wade.

Mawson's vision of unravelling and ordering the Precambrian rocks of the Flinders Ranges had been largely realised but success in finding fossils (other than stromatolites), which he felt must lie in the thick sedimentary sequence, had eluded him. While David's (as he believed) misguided forays into the Adelaide region had annoyed him, the success of one of his own students in finding the earliest fossil animals was a vindication of his own long dedication to teaching and researching in the northern ranges, as well as being a fitting justification of David's equally dedicated search for evidence of life in the distant past. More recent finds of problematica similar to David's in North America have revived interest in the nature of these supposed 'fossils', with an indication that there may be an organic component in some of them.

Postscript

David's death was a significant event in the development of Australian geology. It also came at a time which marked a watershed in the life and career of Douglas Mawson. At the age of fifty-two his direct involvement with Antarctic exploration had ended and he began his most sustained period of research into South Australian geology. Between 1935 and 1952 (the year he retired), Mawson published 30 significant papers, over half of them concerned with the Precambrian rocks of the Flinders Ranges. (This compares with a similar number of papers over a period twice as long between 1904 and 1934 on a wide variety of topics). The death of Walter Howchin in 1937, three years after David, saw the approach of the end of the old order of Australian geologists, and in South Australia, as elsewhere in Australia, a new generation of native-born and trained geologists had emerged, all of them graduates of Mawson's department and including, in addition to R. C. Sprigg, many others, notably E. A. Rudd, L. W. Parkin, Paul Hossfeld and A. Kleeman. Many of Mawson's later papers were co-authored with junior members of his department or former students.

The lives of T. W. Edgeworth David and Douglas Mawson spanned the years when geology became established as a profession in Australia. David was the pioneer in the professionalising of the science, his department at Sydney, in the early years of the century, producing a galaxy of talented men and women from which Mawson was to emerge as the shining star, not least because of his international reputation as an Antarctic explorer. David was also the first, and highly successful, networker in Australian geology and Mawson, a generation later, by establishing his own equally effective department, extended the net and through his effort and inspiration, created an influence which is still potent at the close of the twentieth century.

Acknowledgments

I am indebted to Professor David Branagan of The University of Sydney for his critical review of the manuscript, and for the benefit of his extensive knowledge of David; in particular, for suggesting alternative interpretations of aspects of what was not always a smooth relationship.

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The Mawson-David correspondence is housed in the David archive at the Fisher Library, The University of Sydney.

NOTE ON THE ORIGIN OF FRESHWATER CRAYFISH OCCURING ON KANGAROO ISLAND.

BY W. ZEIDLER

Summary

ZEIDLER, W. (2000). Two species of freshwater crayfish occur on Kangaroo Island. The common yabbie *Cherax destructor* Clark, 1936 and the marron, *Cherax tenuimanus* (Smith, 1912).

NOTE ON THE ORIGIN OF FRESHWATER CRAYFISH OCCURRING ON KANGAROO ISLAND, SOUTH AUSTRALIA

Two species of freshwater crayfish occur on Kangaroo Island. The common yabbie *Cherax destructor* Clark, 1936 and the marron, *Cherax tenuimanus* (Smith, 1912).

The marron, a riverine species native to south Western Australia, is an obvious introduction. Marron are highly desirable as an aquaculture species (Morrissy 1984) and were introduced to Queensland and northern New South Wales in 1979 (Austin 1985). They were introduced to Kangaroo Island, for aquaculture, in the early 1980s but soon escaped and by the mid 1980s became established in the nearby Ravine des Casoars. Marron have since spread, or have been translocated, so that they are now also well established in Rocky River and the De Mole River with some patchy occurrences in Middle River and Cygnet River (Nicholls 1995) and probably also occur in other permanent water on the Island.

The origin of *Cherax destructor* is more difficult to determine. In 1979 and 1981 I conducted extensive surveys of Kangaroo Island in order to determine the presence of freshwater crayfish and to sample for other freshwater invertebrates. I found populations of *Cherax destructor* in most freshwater streams on the eastern half of the Island, extending as far west as the upper reaches of the South-West River (Zeidler 1982). Although I did not take quantitative samples at the time I noted that *C. destructor* was less abundant as I travelled west of Cygnet River suggesting that the species was spreading west or had reached some geographical barrier at the South-West River. There seemed no reason for its absence in apparently suitable habitats in the Flinders Chase region. At the time I assumed that the Kangaroo Island population of *C. destructor* had been introduced or had become isolated when the Island separated from the mainland. The species is relatively common on the Fleurieu Peninsula.

Campbell *et al.* (1994) who conducted genetic studies of *Cherax destructor* and *C. albidus* from South Australia and western Victoria, also examined a Kangaroo Island population from Stunsail Boom River. They found that the Kangaroo Island population lacked the genetic divergence characteristic of most of the mainland populations. A lack of genetic divergence is typical of introduced populations and they concluded that the crayfish populating Kangaroo Island are not endemic but have been introduced.

Recently I came across some old correspondence, addressed to Herbert Hale, dated 27 Feb. 1946 which states that some 20 years previous yabbies were introduced to 'Cygnet River about one mile up from the bridge on the Kingscote-Hog Bay main road' from 'the Torrens at West Marden'. The same correspondence states that more specimens were introduced to Cygnet River in about 1938 and that some were also put in the Middle River.

Despite the introduction of yabbies to Cygnet River in about 1926 none were caught almost 20 years later ('we have tried in the Cygnet River on several occasions, to see if we could catch yabbies, but have not had any luck') indicating that the yabbies had difficulty becoming established. The fact that yabbies are now abundant in Cygnet River, and are easily caught, suggests that they were not present prior to the above mentioned introduction. Their spread west seems to have been a slow process.

In 1986 I received a number of specimens of both *C. tenuimanus* and *C. destructor* caught in the Ravine des Casoars from the park ranger at Flinders Chase, Mr Terry Dennis. This was quite alarming because apart from confirming the establishment of the marron in this once crayfish-free environment, it also confirmed that the common yabbie, *Cherax destructor*, had also been introduced as both were absent in 1981. Judging by the topography of Flinders Chase and the apparent slow rate at which *C. destructor* became established in the eastern part of the Island a deliberate introduction to Flinders Chase of this species seems the only logical conclusion.

Without a base-line knowledge of the freshwater fauna of Kangaroo Island prior to the introduction of freshwater crayfish it is impossible to ascertain the ecological implications of such introductions. It is interesting to note that *C. destructor*, a very successful and invasive species, had difficulty in becoming established in Cygnet River.

Despite local knowledge of the existence of freshwater crayfish on Kangaroo Island since about 1926 the only record in the literature up until 1982 (Zeidler 1982) was that of Riek (1969) who reported a species of *Geocharax* from Kangaroo Island. Unfortunately he gave no precise locality data and the record seemed dubious. A search of collections in all Australian museums failed to confirm the presence of this genus on the Island (Gross *et al.* 1979) and no specimens, or evidence (remains) of this genus were found during my surveys of 1979 and 1981. I am thus reasonably confident that Riek's record is erroneous. Most likely it was based on a specimen labelled 'KI' referring to King Island, Bass Strait, which is a known habitat for species of this genus.

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CONTENTS

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VOLUME 33 PART 2
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CONTENTS:

ARTICLES

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BY R.M. KRISTENSEN AND B.S. MACKNESS

Summary

KRISTENSEN, R.M. AND MACKNESS, B.S. (2000). A new species of marine tardigrade, *Batillipes lesteri* sp. nov. is described from beach sand collected at below low tide at Henley Beach, Adelaide, South Australia. Eighteen specimens including both sexes, four-toed larvae and juveniles were recovered. The new species differs from all other members of the Batillipedidae by its combination of toe patterns, fourth lateral projections caudal apparatus. It is the first member of the genus to be described from South Australia and only the third species to be recorded from the Southern Hemisphere.

FIRST RECORD OF THE MARINE TARDIGRADE GENUS *BATILLIPES* (ARTHROTARDIGRADA: BATILLIPEDIDAE) FROM SOUTH AUSTRALIA WITH A DESCRIPTION OF A NEW SPECIES

R. M. KRISTENSEN AND B. S. MACKNESS

Dedication: To the late Alan Bird who provided the first illuminating studies on South Australian tardigrades.

KRISTENSEN, R. M. & MACKNESS, B. S. 2000. First record of the marine tardigrade genus *Batillipes* (Arthrotardigrada: Batillipedidae) from South Australia with a description of a new species. *Records of the South Australian Museum* **33**(2): 73–87.

A new species of marine tardigrade, *Batillipes lesteri* sp. nov. is described from beach sand collected at below low tide at Henley Beach, Adelaide, South Australia. Eighteen specimens including both sexes, four-toed larvae and juveniles were recovered. The new species differs from all other members of the Batillipedidae by its combination of toe patterns, fourth lateral projections and caudal apparatus. It is the first member of the genus to be described from South Australia and only the third species to be recorded from the Southern Hemisphere.

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The interstitial heterotardigrade genus *Batillipes* was first described by Richters (1909) based on specimens of *B. mirus* from Kieler Bay, in the Baltic Sea. Eight years later, Hay (1917) described *B. caudatus* obtained from algae from jetties at Beaufort, North Carolina. This American species was later incorrectly synonymised by Marcus (1929) with *B. mirus*. Marcus (1946) described a third species, *B. pennaki* from the Atlantic coasts of North and South America. Since that time many more new species have been discovered and named: *B. similis* Schulz, 1955; *B. carnonensis* Fize, 1957; *B. littoralis*, *B. phreaticus* Renaud-Debyser, 1959; *B. friaufi* Riggin, 1962; *B. annulatus*, De Zio 1962; *B. bullacaudatus* McGinty and Higgins, 1968; *B. gilmartini* McGinty, 1969; *B. dicrocercus* Pollock, 1970; *B. acaudatus*, *B. tubernatis* Pollock, 1971; *B. noerrevangi*, *B. roscoffensis* Kristensen, 1978; *B. adriaticus* Grimaldi de Zio *et al.*, 1979; *B. africanus*, *B. marcelli* Morone De Lucia *et al.*, 1988; *B. tridentatus* Pollock, 1989; *B. crassipes* Tchesunov and Mokievsky, 1995; *B. philippinensis*, *B. longispinosus* and *B. orientalis* Chang and Rho, 1997a,b. Most recently, Rho *et al.* 1999 described a new species *B. rotundiculus* and provided a key to eight batillipedid tardigrades from Korea.

Mackness (1999) recorded the first Australian members of *Batillipes* from beaches in Victoria but was unable to identify the animals to species level due to poor preservation. This paper presents the first record of the genus from South Australia and describes a new species based on 18 specimens collected subtidally from a beach in South Australia. Furthermore, the paper describes its life cycle including the four-toed larva, juveniles, young adults as well as their sexual dimorphism.

Materials And Methods

Two sand samples (2 x 750 ml approx.) were collected on 6 November, 1995 by one of us (BM) at Henley Beach, Adelaide, South Australia (34° 55'S, 138° 30'E). One sample (A1) was taken at the low tide level and the other (A2), was taken at one metre water depth (subtidal). Tardigrades were only obtained from the subtidal sample. The tardigrades were sorted out alive at the Queensland Museum by RMK, two days after they were received. Each sample was fresh-water 'shocked' following the procedure set out by Kristensen and Higgins (1984). This involved soaking the sediments in fresh water for about 20 seconds and then swirling them around. This osmotically incapacitated the tardigrades which were collected after the heavier material had settled by decanting off the liquid through a 63 µm mesh filter. The meiofauna was sorted using a binocular microscope (40–80 x magnifications) and then examined using phase contrast microscopes (1000 x magnifications). A few tardigrades were removed and placed in sea water where they quickly recovered. All drawings were made using camera-lucida techniques on live animals. The reason for using live material for illustrations is that the lipoid eyes and the hard structures in the pharyngeal disappear in all known permanent mounts.

Live tardigrades adhering with their suction discs to the cover glass were then preserved in 2% buffered formalin added under the cover glass. Permanent mounts were made by adding specimens to a glycerine solution (4%) under cover glasses. After two days dehydration, the cover glasses were ringed with Glyceel. Measurements were only made on permanent mounts and taken to the nearest micron using an ocular micrometer. Comparisons were made with reference collections held in the Zoological Museum of the University of Copenhagen (ZMUC) and with original type descriptions from the literature. Measurements for 12 specimens are provided in Tables 1–3.

SYSTEMATICS

Order Arthrotardigrada Marcus, 1927

Family BATILLIPEDIDAE Ramazzotti, 1962

Revised family diagnosis

Arthrotardigrade with large median cirrus present and secondary clava dome-shaped. Lateral cirrus and primary clava with a common pedestal. Internal cirrus and median cirrus with well-developed cirrophorus, external cirrus with indistinct cirrophorus. All cephalic cirri without scapus and flagellum. With four toes (in larvae) or six toes (in adults) of different lengths, with adhesive or suction disc at terminus of toe stalk. Claws absent. Cuticular seminal receptacles absent.

Discussion

This family had originally included the genera *Batillipes* and *Orzeliscus* Marcus. In this paper the family Orzeliscidae is considered as a sister group of the family Halechiniscidae and not the Batillipedidae. The Batillipidedae is therefore currently regarded as generically monotypic.

Batillipes Richters, 1909

Generic diagnosis

As Batillipedidae is monogeneric, the generic diagnosis is the same as that for the family.

Type species: Batillipes mirus Richters, 1909 by monotypy.

Type locality: Kieler Bay, Baltic Sea.

Discussion

The original description of *B. mirus* was written in German and perhaps this is the reason that this excellent early description has been overlooked. *Batillipes mirus* is a very large arthrotardigrade up to 720 µm (mean = 400–600 µm) with spade-shaped suction discs, similar to those of *B. tubernatis* illustrated by McKirdy (1975). The type material of *B. mirus* was collected subtidally (20 m water depth) and not in sandy beaches as nearly all later records for *B. mirus* worldwide. In the comprehensive review by McKirdy (1975) of the genus *Batillipes*, six species were examined carefully. The American '*B. mirus*' is a middle-sized batillipedid (about 160 µm) with ovoid or round suction discs. It is very clear that these animals are not the same as the type species. It may well be that all tidal animals called '*B. mirus*' are in fact *B. caudatus* described by Hay (1917) from North Carolina. This species was later incorrectly synonymised by Marcus (1929) with *B. mirus*. The cosmopolitan distribution (Table 4) of *B. mirus* must therefore be considered doubtful and new, worldwide samplings are necessary.

Batillipes lesteri n. sp.

(Figs 1–3, Tables 1–3)

Material examined

6 females, 5 males, 4 juveniles and 3 four-toed larvae collected sublittorally (1 m in water depth from the mean low tide), medium coarse sand from Henley Beach, Adelaide, South Australia. The sand samples were collected by B.M. on 6 November 1995. Holotype and seven paratypes will be deposited in the Queensland Museum. The other paratypes will be deposited in the Zoological Museum of the University of Copenhagen (ZMUC). Only 14 specimens were measured. In this paper, only the measurements of 12 specimens are given.

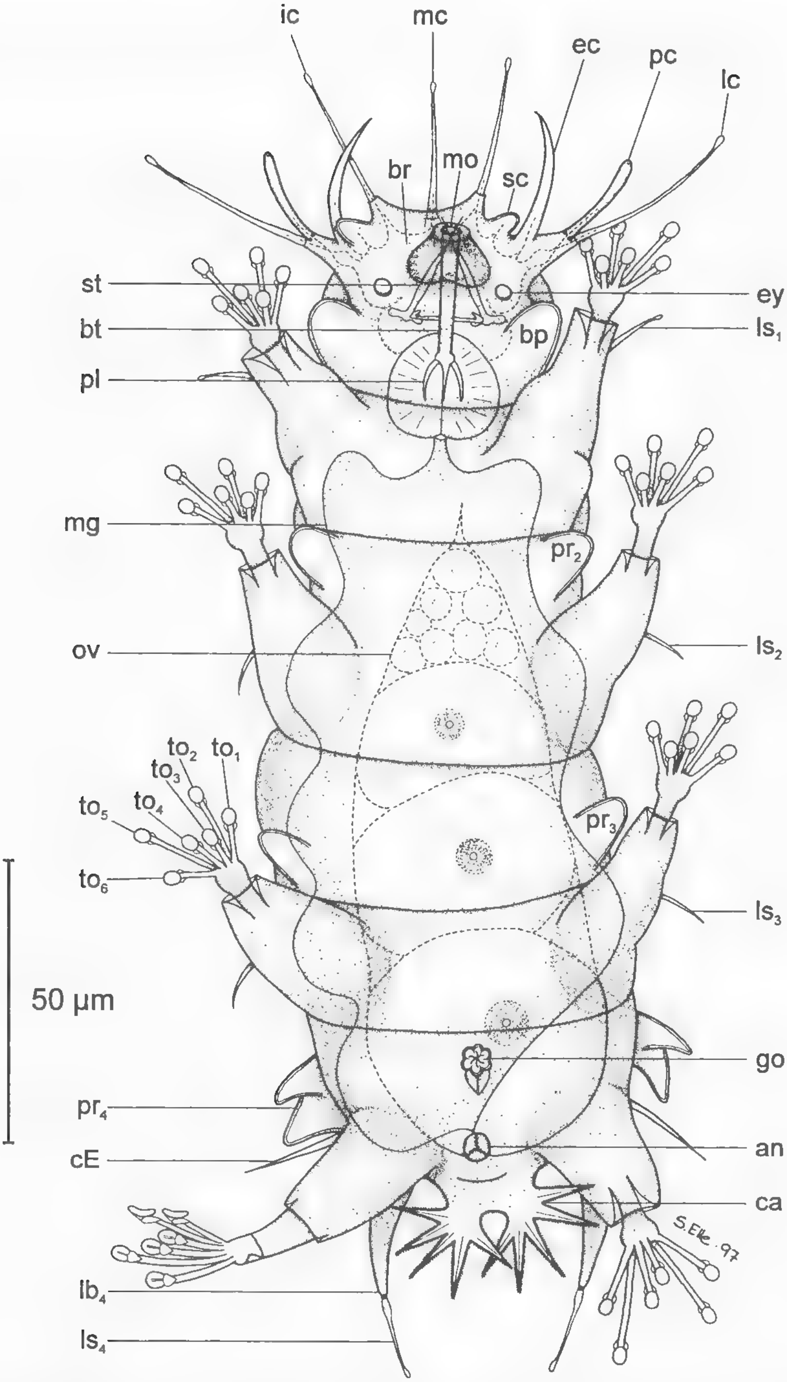

FIGURE 1. *Batillipes lesteri* n. sp. Holotypic female, ventral view. Scale bar equals 50 µm. Abbreviations: an, anus; bl, body length; bp, buccal projection; br, brain; bt, buccal tube; bw, body width; ca, caudal appendage; cE, cirrus E; ec, external cirrus; ey, eye; go, gonopore; ic, internal cirrus; lb_4, the base of leg IV sensory structure; ls_1-ls_3, leg I to leg III spines; ls_4, the spine of leg IV sensory structure; mc, median cirrus; mg, midgut; mo, mouth; oo, oocyte; ov, ovary; pc, primary clava; pl, placoid; pr_2–pr_4, lateral projections; sc, secondary clava; sl, stylet length; ss, stylet support; sv, seminal vesicle; te, testis; to_1-to_6, toe 1 to toe 6.

TABLE 1. Morphometry of *Batillipes lesteri* n. sp. Females. All measurements to the nearest micron.

Specimen	**Holotype Female** (Specimen 1)	**Female 2** large eyes (Specimen 4)	**Female 3** Part. destroyed (Specimen 5)	**Female 4** Immature (Specimen 6)
Body length	178.2 (178)	142.2 (142)	162.5 (163)	115.8 (116)
Body width	72.8 (73)	65.8 (66)	63.8 (64)	49.7 (50)
Buccal tube	25.0 (25)	23.7 (24)	22.0 (22)	20.2 (20)
Stylet length	23.1 (23)	22.5 (23)	20.8 (21)	19.5 (20)
Stylet support	6.0 (6)	6.0 (6)	5.8 (6)	4.8 (5)
Placoid	7.2 (7)	7.2 (7)	7.0 (7)	6.0 (6)
Median cirrus	27.7 (28)	24.4 (24)	25.2 (25)	19.2 (19)
Internal cirrus	29.7 (30)	25.3 (25)	25.5 (26)	21.3 (21)
External cirri	23.2 (23)	17.8 (18)	18.9 (19)	13.8 (14)
Lateral cirri	37.8 (38)	35.6 (36)	35.3 (35)	29.4 (29)
Primary clavae	14.5 (15)	14.9 (15)	12.7 (13)	12.2 (12)
Second. clavae	5.6 (6)	5.1 (5)	5.2 (5)	6.1 (6)
Cirri E	23.2 (23)	21.5 (22)	24.4 (24)	21.0 (21)
Leg IV base	23.1 (23)	19.2 (19)	18.3 (18)	13.4 (13)
Leg IV spine	16.5 (17)	15.0 (15)	15.8 (16)	12.2 (12)
Leg III spine	13.0 (13)	12.1 (12)	10.2 (10)	10.4 (10)
Leg II spine	12.5 (13)	11.9 (12)	10.1 (10)	10.0 (10)
Leg I spine	10.0 (10)	10.5 (11)	9.7 (10)	9.5 (10)
Buccal project.	9.9 (10)	7.7 (8)	8.2 (8)	7.5 (8)
Projection 2	12.5 (13)	8.1 (8)	11.4 (12)	8.9 (9)
Projection 3	13.2 (13)	10.3 (10)	12.3 (12)	9.5 (10)
Projection 4	15.3 (15)	15.2 (15)	13.1 (13)	11.7 (12)
Caudal apparatus apparatus (width x length)	21.0 x 26.4 (21 x 26) bilobed, each with 5 spikes	16.8 x 19.2 (17 x 19) bilobed, each with 3 spikes	20.0 x 15.0 (20 x 15) bilobed, each with 3 spikes	16.0 x 12.9 (16 x 13) bilobed, each with 4 spikes
Leg 1 (toe 1)	9.5 (10)	9.5 (10)	9.5 (10)	9.5 (10)
(toe 2)	5.9 (6)	5.7 (6)	5.6 (6)	5.2 (5)
(toe 3)	12.5 (13)	14.1 (14)	12.8 (13)	12.0 (12)
(toe 4)	7.9 (8)	7.8 (8)	7.9 (8)	7.2 (7)
(toe 5)	17.1 (17)	17.2 (17)	16.1 (16)	15.0 (15)
(toe 6)	10.5 (11)	9.8 (10)	9.8 (10)	10.0 (10)
Leg IV (toe 1)	13.8 (14)	12.9 (13)	12.4 (12)	10.8 (11)
(toe 2)	19.8 (20)	17.0 (17)	18.4 (18)	15.2 (15)
(toe 3)	8.5 (9)	7.5 (8)	7.8 (8)	5.8 (6)
(toe 4)	13.2 (13)	11.7 (12)	11.3 (11)	10.2 (10)
(toe 5)	22.4 (22)	18.2 (18)	21.5 (22)	16.0 (16)
(toe 6)	13.4 (13)	10.6 (11)	11.8 (12)	9.8 (10)
Gonopore/Anus	11.0 (11)	11.2 (11)	10.2 (10)	rosette not present
Ovary	3 eggs	2 eggs	2 eggs	immature
Toe formula	6-6-6-6	6-6-6-6	6-6-6-6	6-6-6-6

Diagnosis

Middle-sized *Batillipes* with large lipoid eyes, swollen tips on lateral, internal and median cirri as well as on fourth leg spine; enlarged fourth leg spine with a van der Land body separating the cirrophore from spinous part of the leg sense organ. The prominent lateral projection between legs III and IV is two-pointed in adults and juveniles, one-pointed in larvae. The caudal apparatus is an ala-like structure with thin cuticular fibres often covered with detritus. This structure varies extremely from simple bilobed to highly furcated (4–10 spikes). Slightly sexually dimorphic (females larger than males); females with wider gonopore-anus distance than males, and females with two-valved cuticular structures associated with the rosette gonopore system. Uneven 3rd (short) and 4th (long) toe on fourth leg, all toes with ovoid suction discs.

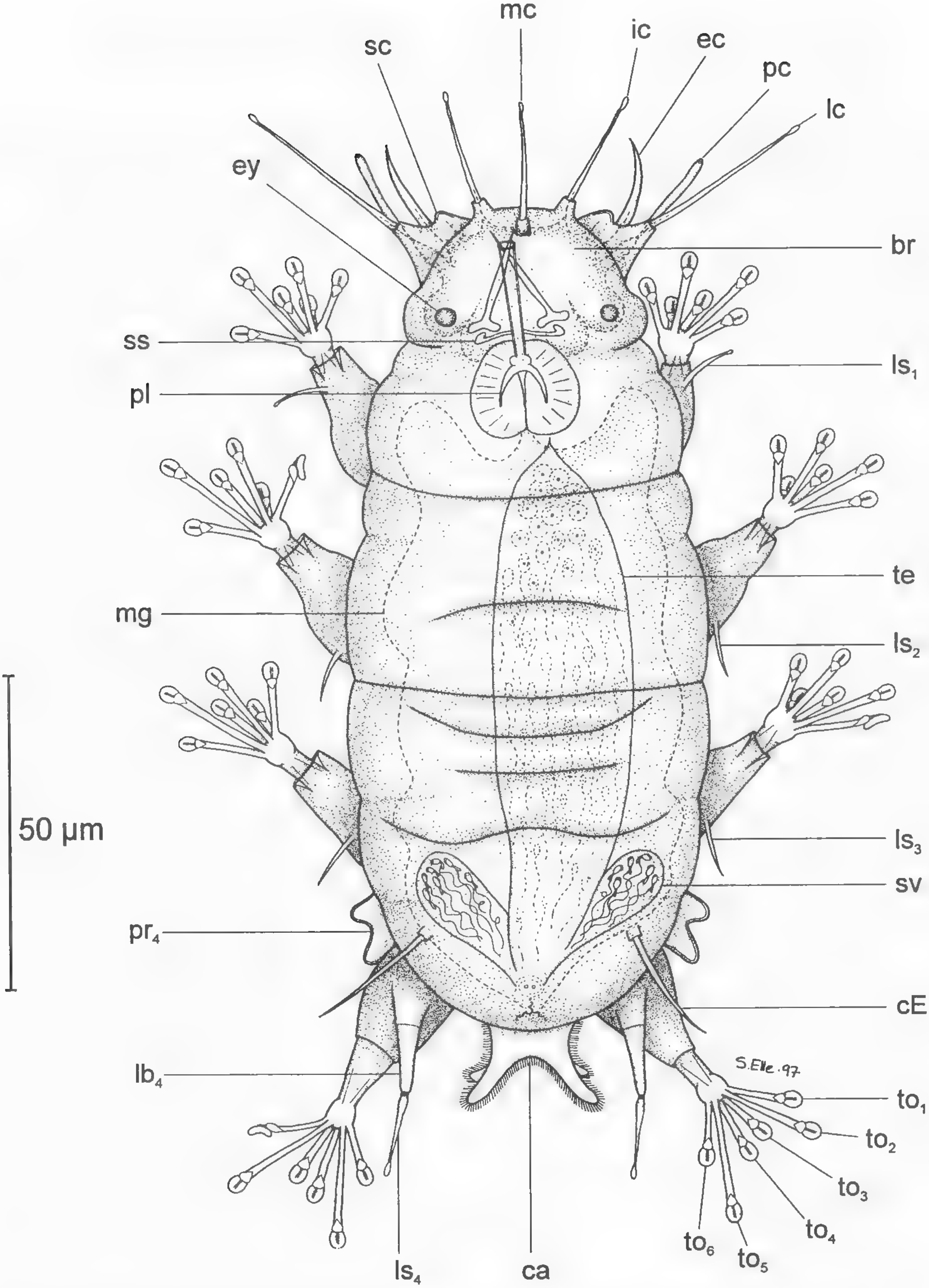

FIGURE 2. *Batillipes lesteri* n. sp. Allotypic male, dorsal view. Scale bar equals 50 µm. Abbreviations as for Fig. 1.

TABLE 2. Morphometry of *Batillipes lesteri* n. sp. Males. All measurements to the nearest micron.

Specimen	**Allotypic male** (Specimen 2)	**Male 2** vent./gonopore (Specimen 7)	**Male 3** lateral (Specimen 8)	**Male 4** Imm. Testis (Specimen 9)
Body length	133.7 (134)	174.2 (174)	129.0 (130)	112.5 (113)
Body width	66.8 (67)	73.5 (73)	lateral view	47.8 (48)
Buccal tube	21.7 (22)	21.8 (22)	18.8 (19)	17.1 (17)
Stylet length	19.8 (20)	21.0 (21)	17.5 (18)	15.3 (15)
Stylet support	5.9 (6)	6.2 (6)	5.3 (5)	5.2 (5)
Placoid	6.6 (7)	7.1 (7)	7.0 (7)	6.0 (6)
Median cirrus	23.0 (23)	28.1 (28)	22.8 (23)	19.8 (20)
Internal cirrus	23.1 (23)	28.9 (29)	23.0 (23)	22.2 (22)
External cirri	19.8 (20)	19.6 (20)	15.4 (15)	14.9 (15)
Lateral cirri	31.5 (32)	38.9 (39)	32.5 (33)	33.1 (33)
Primary clavae	13.8 (14)	15.0 (15)	13.0 (13)	11.7 (12)
Second. clavae	5.2 (5)	5.3 (5)	5.1 (5)	4.9 (5)
Cirri E	21.1 (21)	22.5 (23)	21.0 (21)	20.2 (20)
Leg IV base	18.3 (18)	17.8 (18)	13.5 (14)	15.6 (16)
Leg IV spine	15.8 (16)	18.0 (18)	12.8 (13)	13.3 (13)
Leg III spine	10.5 (11)	13.2 (13)	10.2 (10)	9.8 (10)
Leg II spine	10.5 (11)	12.1 (12)	9.8 (10)	9.4 (9)
Leg I spine	9.5 (10)	12.0 (12)	8.9 (9)	9.1 (9)
Buccal project.	8.0 (8)	9.5 (10)	6.2 (6)	7.2 (7)
Projection 2	9.8 (10)	10.8 (11)	7.5 (8)	9.5 (10)
Projection 3	10.3 (10)	12.2 (12)	8.0 (8)	10.2 (10)
Projection 4	11.8 (12)	15.8 (16)	13.4 (13)	12.9 (13)
Caudal apparatus (width x length)	16.2 x 17.8 (16 x 18) bilobed, each with 2 spikes	15.8 x 16.0 (16 x 16) bilobed, each with 2 spikes	11.5 x 13.0 (12 x 13) bilobed, each with 2 spikes	15.0 x 13.2 (15 x 13) bilobed, each with 2 spikes
Leg 1 (toe 1)	9.9 (10)	10.1 (10)	8.5 (9)	7.2 (7)
(toe 2)	5.9 (6)	6.0 (6)	5.0 (5)	4.9 (5)
(toe 3)	12.5 (13)	15.3 (15)	13.8 (14)	11.9 (12)
(toe 4)	7.9 (8)	9.2 (9)	8.2 (8)	6.1 (6)
(toe 5)	17.1 (17)	18.5 (19)	15.0 (15)	15.2 (15)
(toe 6)	9.2 (9)	11.6 (12)	9.8 (10)	8.0 (8)
Leg IV (toe 1)	12.5 (13)	14.1 (14)	10.2 (10)	10.1 (10)
(toe 2)	18.4 (18)	19.4 (19)	15.8 (16)	14.7 (15)
(toe 3)	8.5 (9)	7.5 (8)	6.2 (6)	5.2 (5)
(toe 4)	11.5 (12)	12.6 (13)	10.1 (10)	10.0 (10)
(toe 5)	21.0 (21)	21.7 (22)	18.2 (18)	15.3 (15)
(toe 6)	11.2 (11)	11.8 (12)	9.4 (9)	9.2 (9)
Gonopore/Anus	3.3 (3)	4.2 (4)	3.0 (3)	2.9 (3)
Testis	mature sperm	mature sperm	without seminal vesicles	without seminal vesicles
Toe formula	6-6-6-6	6-6-6-6	6-6-6-6	6-6-6-6

Description

Holotype

Adult female (Fig. 1) with body 178 µm long measured excluding caudal appendage and 73 µm wide between legs II and III. Head distinguished from body by a constriction beneath lateral cirri and primary clavae. Head width 45 µm between bases of lateral cirri. Median cirrus unpaired, with large cirrophore and swollen tip (28 µm). Internal cirri also with large cirrophores and swollen tips (30 µm) directed anteriorly. External cirri horn-shaped (23 µm long) with indistinct cirrophores. Primary clavae moderately long (15 µm), thick and tube-shaped. Primary clava and lateral cirrus with a common pedestal (cirrophore of lateral cirrus). Primary clava with a thick cuticular annulus (van der Land body) inside base. Lateral

TABLE 3. Morphometry of *Batillipes lesteri* n. sp. Larva and Juveniles. All measurements to the nearest micron.

Specimen	**Four-toed larva** (Fig. 3) (First instar) (Specimen 3)	**Four-toed larva 2** (First instar) (Specimen 10)	**Juvenile 2** (Third instar) (Specimen 11)	**Juvenile 3** (Fourth instar) (Specimen 12)
Body length	76.5 (77)	78.5 (79)	85.8 (86)	105.2 (105)
Body width	29.7 (30)	27.9 (28)	29.7 (30)	43.8 (44)
Buccal tube	16.5 (17)	15.7 (16)	simplex	18.2 (18)
Stylet length	13.8 (14)	15.2 (15)	simplex	16.5 (17)
Stylet support	3.9 (4)	3.8 (4)	simplex	5.0 (5)
Placoid	4.6 (5)	4.2 (4)	simplex	6.3 (6)
Median cirrus	19.5 (20)	18.2 (18)	20.2 (20)	19.1 (19)
Internal cirrus	20.4 (20)	18.9 (19)	21.1 (21)	20.3 (20)
External cirri	10.5 (11)	10.2 (10)	13.2 (13)	14.4 (14)
Lateral cirri	29.7 (30)	28.9 (29)	29.7 (30)	30.7 (31)
Primary clavae	9.5 (10)	9.0 (9)	9.9 (10)	12.6 (13)
Second. clavae	2.6 (3)	3.7 (4)	3.3 (3)	5.0 (5)
Cirri E	19.8 (20)	19.0 (19)	19.1 (19)	20.1 (20)
Leg IV base	9.2 (9)	10.2 (10)	8.5 (9)	12.8 (13)
Leg IV spine	9.2 (9)	9.8 (10)	8.7 (9)	13.0 (13)
Leg III spine	9.9 (10)	9.5 (10)	9.2 (9)	9.3 (9)
Leg II spine	9.9 (10)	9.2 (9)	9.0 (9)	9.0 (9)
Leg I spine	8.5 (9)	8.0 (8)	8.7 (9)	8.7 (9)
Buccal project.	5.9 (6)	5.0 (5)	5.9 (6)	5.8 (6)
Projection 2	6.6 (7)	6.2 (6)	5.9 (6)	6.2 (6)
Projection 3	7.2 (7)	7.4 (7)	7.9 (8)	6.7 (7)
Projection 4	8.5 (9)	10.0 (10)	9.9 (10)	9.1 (9)
Caudal apparatus (width x length)	6.2 x 4.6 (6 x 5) bilobed, each with one spike	8.2 x 10.5 (8 x 11) bilobed with blunt tip	6.8 x 5.2 (7 x 5) bilobed, each with two small spikes	11.2 x 12.7 (11 x 12) bilobed, each with two spikes
Leg 1 (toe 1)	5.2 (5)	5.2 (5)	5.2 (5)	8.2 (8)
(toe 2)	0	0	0	4.9 (5)
(toe 3)	11.2 (11)	12.1 (12)	7.9 (8)	13.7 (14)
(toe 4)	5.2 (5)	6.8 (7)	5.9 (6)	7.0 (7)
(toe 5)	0	0	9.9 (10)	15.0 (15)
(toe 6)	7.2 (7)	8.2 (8)	7.6 (8)	9.6 (10)
Leg IV (toe 1)	7.9 (8)	7.2 (7)	9.9 (10)	9.1 (9)
(toe 2)	14.2 (14)	14.0 (14)	13.2 (13)	15.8 (16)
(toe 3)	0	0	4.6 (5)	5.7 (6)
(toe 4)	0	0	7.9 (8)	9.2 (10)
(toe 5)	11.2 (11)	10.1 (10)	14.5 (15)	16.4 (16)
(toe 6)	8 .2 (8)	8.0 (8)	9.2 (9)	9.0 (9)
Gonopore/Anus	lacking	lacking	gonopore lacking/ anus present	gonopore lacking/ anus present
Toe formula	4-4-4-4	4-4-4-4	5-6-6-6	6-6-6-6

cirri long and tapered terminating in prominent swelling (38 μm). Secondary clavae (base 6 μm) located between internal and external cirri at frontal edge of head. Two large lipoid eyespots present only in live animal consisting of one very large ball-shaped lipoid droplet. The hyalin spherical structure is seen on the inside of the external brain lobe (protocerebrum). It is supposed they are of lipid composition based on their solubility in alcohol and glycerol. Pharyngeal bulb subcircular (18 μm x 21 μm) located between legs I. In optical cross-section, bulb is trilobate, each lobe with a calcium carbonate encrusted placoid (7 μm). Buccal tube straight and moderately long (25 μm) with (3 μm) width. Buccal tube extends inside pharyngeal bulb attaching placoids via three apophyses. Ventral mouth as in characteristic pouting in typical *Batillipes* form (*sensu* Kristensen 1978). Stylet supports straight (6 µm) with support knob showing slight deflection anteriorly. Support knobs linked on large furca of stylet. Stylets length 23 µm.

Spines present on all legs. Spine of legs I located more distally than all other spines. Spines on legs II–IV located proximally to body. Increasing size of spines from legs I–IV, 10.0 µm, 12.5 µm, 13.0 µm, 16.5 µm + 23.1 µm respectively. Fourth leg spine very long with large base (cirrophore) and a cuticular annulus (van der Land body) separating base from spine which is the true sense organ. Total length of whole fourth leg sensory structure 49.6 µm. First and fourth leg spines with swollen tips as in cephalic cirri. Cirri E moderately long (23 µm) and sharply pointed with distinct cirrophore. Ventral tongue-shaped projections in front of leg I (10 µm), leg II (13 µm long) and leg III (13 µm long). Lateral projection in front of leg IV bifurcate (15 µm long). Caudal apparatus ala-like and strongly furcated (2 x 5 spikes). Cuticle of caudal apparatus has fine hairs; it is covered with bacteria and detritus. Gonopore rosette-shaped with six identical segments. Behind the female gonopore there is a two valved cuticular structure. Gonopore-anus distance is 11 µm. The holotypic female is sexually mature, with three large eggs.

Legs I–IV possessing toes of varying lengths. On leg I, toe 5 is the longest (17 µm) with toes decreasing in size 3, 6, 1, 4 and 2 (13 µm, 11 µm, 8 µm and 6 µm respectively). On legs IV, toes 2 and 3 are unequal in size and conform to toe pattern D (see Table 5). Length of toes in decreasing order of size is 5, 22 µm; 2, 20 µm; 1, 14 µm; 4, 13 µm; 6, 11 µm and 3, 9 µm. Toe discs ovate with conspicuous brace.

Allotype

Adult male (Fig. 2) with body 134 µm long measured excluding caudal appendage, and 67 µm wide between legs II and III. Male is similar to female except for size and differences in shape of projection in front of leg IV which is slightly bilobate, and caudal appendage lobate with only four spikes. Gonopore-anus distance is only 3 µm, meaning that the gonopore nearly connects the anterior branch of a three-lobed anal system. Male gonopore located on a small ovoid papilla. The allotype is sexually mature with two lateral seminal vesicles filled with mature spermatozoa.

The allotype is drawn in dorsal perspective. Dorsal transverse lines indicating segmental plates disappear after fixation. The punctations of the dorsal cuticle (see McKirdy 1975) are very coarse, especially laterally, where the epicuticular pillars, which form the punctations, can be seen using light microscopy. Each lateral pillar is about 2 µm high.

Four-toed larva

The first instar of all species of *Batillipes* is so different from subsequent instars, that the term 'larva' (*sensu* Bertolani *et al.* 1984) is correct. The paratypic larva illustrated (Fig. 3, Table 3) has a body length of 77 µm and body width of 30 µm. It shows typical ontogenetic body proportions with a larger head region in relation to body, lacks the gonopore, the anus is only a slit, and it is not three-lobed. The larva has only four toes instead of the six toes of the adult. Toe 2 and 5 are missing on legs I–III and toes 3 and 4 are missing on leg IV. The leg spines I–III are with a swollen tip, but the leg spine IV is pointed. The projection 4 has only one spike and the caudal appendage is only slightly bilobed.

Juvenile

The animals without gonopore, but with three-lobed anus are called juveniles. At least two instars can be recognized but they could be more numerous. The second instar has the toe formula 5-5-5-6 and the third instar has 5-6-6-6. All sense organs have the characteristics of the adult, but the projection in front of leg IV and the caudal apparatus vary a lot. The differences between males and females can be seen in the size and especially in the caudal apparatus.

Young adults

Animals with gonopores, but with immature reproductive systems are called young females and males. These animals are smaller in size, but are still sexually dimorphic. The young males lack the seminal vesicles with mature spermatozoa while the young females have only small-size oocytes in the ovaries.

Life Cycle

There is no doubt that *B. lesteri* was in the middle of its reproductive cycle when the specimens were collected in November, which is the last month in the Australian Spring. It is unusual to have so many four-toed larvae and juveniles in populations of *Batillipes*. The first instar, the four-toed larva, differed dramatically from the juveniles and adults. It is difficult to interpret just how many instars are involved

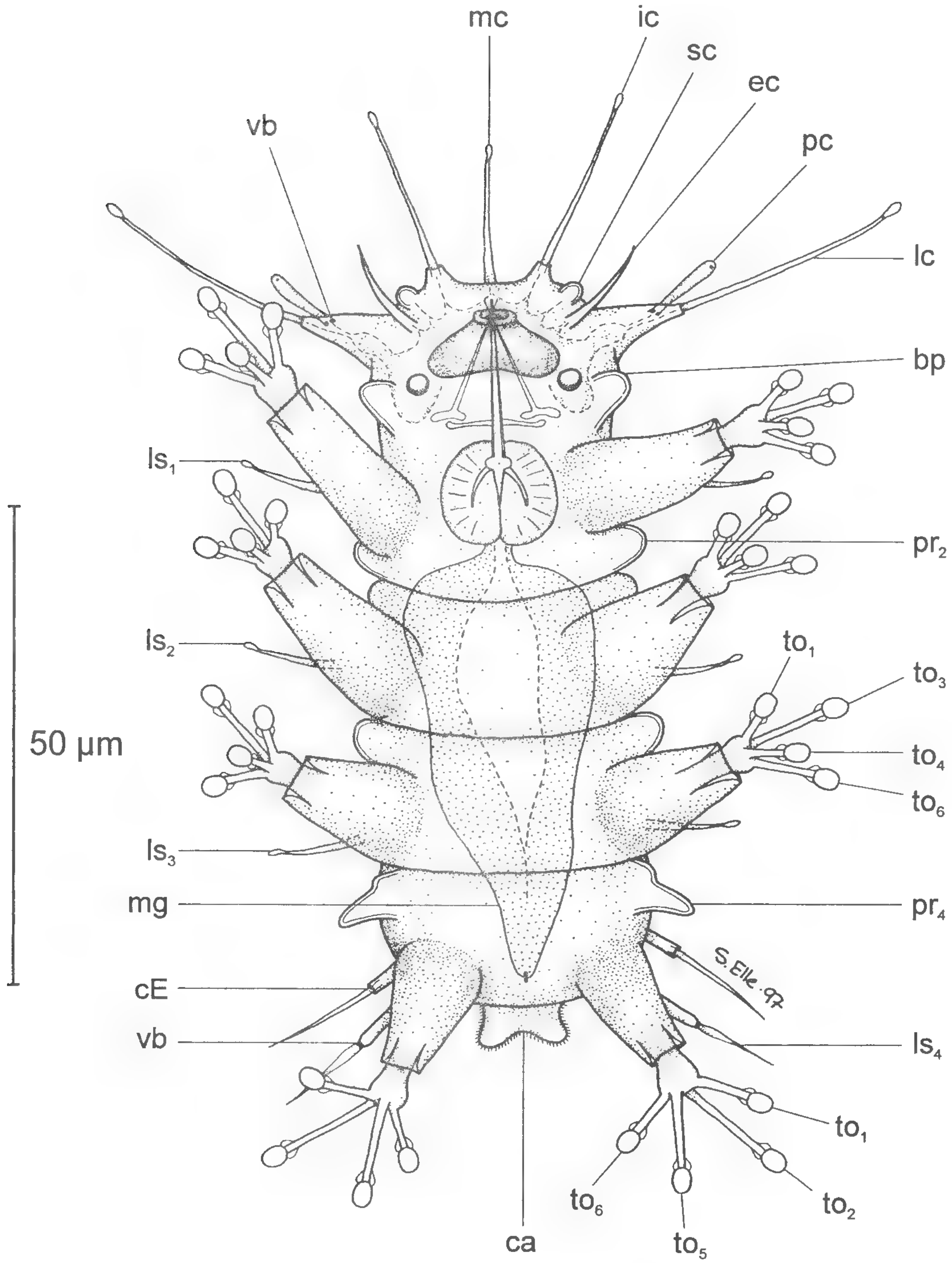

FIGURE 3. *Batillipes lesteri* n. sp. Paratypic four-toed larva. Scale bar equals 50 µm. Abbreviations as for Fig. 1.

TABLE 4. Zoogeographic distribution of species of the genus *Batillipes*. (Southern hemisphere records in bold).

B. acaudatus – England (Pollock, 1971)
B. adriaticus – Italy – (Grimaldi De Zio *et al.*, 1979)
B. africanus – Libéria (Morone De Lucia *et al.*, 1988)
B. annulatus – Italy (De Zio 1962, Grimaldi De Zio *et al.* 1979)
B. bullacaudatus – USA (McGinty & Higgins 1968, Pollock 1970b; Lindgren 1971; McKirdy 1975); Scotland (McIntyre & Murison 1973)
B. carnonensis – France (Fize 1957); Italy (Grimaldi De Zio *et al.* 1980, 1983); USA (Fleeger 1978)
B. crassipes – Russia (Tchesunov & Mokievsky 1995); Korea (Rho *et al.* 1999)
B. dicrocercus – USA (Pollock 1970a, McKirdy 1975, Hummon 1994); Italy (Hummon 1994; Grimaldi De Zio *et al.* 1980, D' Addabbo Gallo *et al.* 1987, Matarrese *et al.* 1996); Poland (Hummon 1994)
B. friaufi – USA (Riggin 1962, McKirdy 1975, Gaugler & Nelson 1997)
B. gilmartini – USA (McGinty 1969. Pollock 1989)
B littoralis – France (Renaud-Debyser 1959, D'Hondt 1970, Renaud-Debyser & Salvat 1963); Italy (Grimaldi De Zio *et al* . 1983, D'Addabbo Gallo *et al* 1987, D'Addabbo Gallo *et al.* 1999, Grimaldi De Zio *et al.* 1999)
B. longispinosus – Korea (Chang & Rho 1997a, Rho *et al.* 1999)
B. marcelli – Italy (Morone De Lucia *et al.* 1988)
B. mirus – Germany (Richters 1909); Wales (Boaden 1963); Ireland (Boaden 1966); Scotland (Pollock 1971; McIntyre & Murison 1973); Norway (Tambs-Lyche 1939–40); Denmark (Fenchel *et. al* 1967, Fenchel 1969, Kristensen 1978); Finland (Purasjoki 1953, Karling 1954–1955); Sweden (Jägersten 1952); North Sea (Remane 1940, Freidrich 1963); Black Sea (Plesa 1963); Germany (Schmidt 1969) Bulgaria (Valkanov 1950, 1954); Romania (Rudescu 1964); Russia (Petelina & Tchesunov 1983, Biserov 1991); France (Baudoin 1952, Swedmark 1956 a,b, Renaud- Debyser 1956, Guérin 1960, Renaud-Mornant & Jouin 1965; D'Hondt 1970,Renaud-Debyser & Salvat 1963); Italy (Papi 1952, D'Addabbo Gallo *et al.* 1987); **Madagascar (Renaud-Mornant 1979)**; USA (Hay 1917, King 1962, McGinty & Higgins 1968, Pollock 1970a, Lindgren 1971, McKirdy 1975, Meyer cited in Pollock 1989, Pollock 1989, Gaugler & Romano 1995, Gaugler & Nelson 1997); Bahamas (Pollock 1970b); **Malaysia (Renaud-Mornant & Serène 1967)**
B. noerrevangi – Denmark (Kristensen 1976, 1978)
B. orientalis – Korea (Chang & Rho 1997, Rho *et al.* 1999))
B. pennaki – Massachusetts, USA (Marcus 1946, Pollock 1970b, McKirdy 1975); **Brazil (Marcus 1946);** France (Renaud-Debyser 1959,Renaud-Debyser & Salvat 1963); Italy (De Zio 1962, 1964, Grimaldi de Zio & D'Addabbo Gallo 1975, Grimaldi De Zio *et al.* 1979, Bertolani *et al.* 1984, D'Addabbo Gallo *et al.* 1987); Spain (Villora-Mofeno & Grimaldi de Zio 1993); India (Rao & Ganapati 1968); Korea (Rho *et al.* 1999)
B. philippinensis – Philippines (Chang & Rho 1997b); Korea (Rho *et al.* 1999)
B. phreaticus – France (Renaud-Debyser 1959, Renaud-Debyser & Salvat 1963); Germany (Riemann 1966); England (Pollock 1971); Spain (Villora-Moreno & Grimaldi De Zio 1993); Italy (D'Addabbo *et al.* 1987).
B. roscoffensis – France (Kristensen 1978)
B. rotundiculus – Korea (Rho *et al.* 1999)
B. similis – Germany (Schulz 1955); Korea (Rho *et al.* 1999) France (Fize 1963); Italy (Grimaldi De Zio *et al.* 1980, D'Addabbo Gallo *et al.* 1999, Grimaldi De Zio *et al.* 1999)
B. tridentatus – Washington & California, USA (Pollock 1989); Korea (Rho *et al.* 1999)
B. tubernatis – Scotland (McIntyre & Eleftheriou 1968, Pollock 1971); Germany (Riemann 1966, Hummon 1994); USA (McKirdy 1975)

before an animal is sexually matured but at least four moults are present before the gonopore is seen. The following instars have been recorded for this species. First instar –the four toed larvae; Second instar – juvenile with toe formula 5-5-5-6; Third instar – juvenile with toe formula 5-6-6-6; Fourth instar juvenile without gonopore but with toe formula 6-6-6-6; Adult—with gonopore and three-lobed anus.

Etymology

Named in honour of curator Dr Lester R. G. Cannon, Queensland Museum, who facilitated our collaboration.

TABLE 5. Patterns of toe length on fourth foot of species of *Batillipes*. (Modified after Pollock 1970a)

A (III & IV equal)	B (I & III equal)	C (II & IV equal)	D (III & IV unequal)
B. acaudatus	*B. phreaticus*	*B. friaufi*	*B. africanus*
B. adriaticus		*B. littoralis*	*B. lesteri*
B. annulatus			*B. tubernatis*
B. bullacaudatus			*B. similis*
B. carnonensis			
B. crassipes			
B. dicrocercus			
B. gilmartini			
B. longispinosus			
B. marcelli			
B. mirus			
B. noerrevangi			
B. orientalis			
B. pennaki			
B. philippinensis			
B. roscoffensis			
B. rotundiculus			
B. tridentatus			

Systematic Discussion

Species of the genus *Batillipes* are amongst the most studied of all marine tardigrades. Their taxonomy remains problematic with relatively few characters commonly used in systematic investigations of the group (McKirdy 1975). Some of the characters used (e.g. conformation of lateral body projections, relative length and shape of cephalic appendages), are directly affected by the physical mounting process. Total body length and width may vary due to cover slip pressure; shrinkage can occur due to the mounting medium and lengths of spines and cirri may be miscalculated because of their orientation to the observer. Internal features such as eyespots and buccal apparatus can also be affected by mounting media and cover slip pressure. Apart from these mechanical problems, there are also a range of other factors to contend with. The caudal appendage of *Batillipes* has often been used in the diagnosis of species but various authors have shown this can vary ontogenetically (Grimaldi de Zio and D'Addabbo Gallo 1975; Morone De Lucia *et al.* 1988). Further ontogenetic variation has been recorded by Kristensen (1978), McGinty and Higgins (1968) and Villora-Morena and Grimaldi de Zio (1993).

Comparative studies have also been made difficult because of the inconsistent nomenclature of toes and the lack of a full range of specimens of both sexes, four-toed larvae and juveniles for many species. In this study, we have used the standard method of numbering toes on the fourth leg with toe 1 being the closest cranially on the right hand side and the toes then numbered sequentially in a clockwise direction. This makes the caudoproximal toe, toe 6 in our scheme (Table 5). Furthermore, the attachment of the toes to the tarsus has systematic value in determining which toe is missing in larvae and in juveniles. At leg 1, the 2nd and 4th toes are ventral, 1st and 6th lateral and 3rd and 5th dorsal on the tarsus. This distribution is functionally correct: the shortest toes are ventral and the longest dorsal.

The relative position of these toes, particularly those on right leg IV has been used as an important taxonomic indicator (Pollock 1970a). Even here problems can arise if the legs are not properly positioned or incorrectly illustrated. It is therefore necessary to have a range of specimens, of both sexes, including juveniles if any meaningful taxonomic decisions are to be made. *Batillipes lesteri* n. sp. differs from all other species of *Batillipes* by having uneven 3rd and 4th toes on leg IV except for *B. africanus, B. similis* and *B. tubernatis*. It differs from *B. tubernatis* by having a caudal apparatus with fine cuticular hairs and differs from *B. africanus* by the males having bilobate caudal appendages with four spikes and females having highly furcated (6–10 spikes) caudal appendages. It differs from *B. similis* by having different primary clava as well as caudal and lateral processes.

Ontogenetic differences between other species of *Batillipes* are seen in the toe formula. Larvae of *B. noerrevangi* lack toe 2 (the smallest one of the adult) and toe 6 on leg I. Larvae of *B. lesteri* also lack toe 2 but instead of toe 6, they lack toe 5 (the longest toe in the adult) on leg I.

Marine tardigrades also go through a life cycle with a number of moults and will vary morphologically at different stages of this cycle including a process called cyclomorphosis (Kristensen 1982) Furthermore the species may vary in morphology according to differences in salinity (Kristensen 1978). A proper analysis of both sexual and ontogenetic variations is necessary in many instances before new taxa should be raised.

The new species of *Batillipes* is only the third recorded for the Southern Hemisphere. A zoogeographic analysis of the 24 species recorded so far (Table 4) shows a singular distributional bias towards the northern hemisphere. This is probably more an artefact of where marine tardigradologists have been working and collecting rather than any zoogeographic pattern. In this analysis, most *Batillipes* species are still primarily known from their type localities with only three species *B. mirus*, *B. pennaki* and *B. phreaticus* having more cosmopolitan distributions.

Several studies have shown that certain species of *Batillipes* live sympatrically occupying specific regions of the littoral environment (Renaud-Debyser 1959, Schmidt 1969, Lindgren 1971). Furthermore, Renaud-Debyser (1959) and Pollock (1975) have demonstrated that *Batillipes* shows tolerances and preferences to water content, temperature, light and salinity. This predicates that any understanding of the distribution of species of *Batillipes* at any location must take all these factors into account. Some beaches may have an almost monotypic batilliped fauna while others may support several species in different locations. Further ecological studies and collecting of Australian marine tardigrades is needed to clarify whether these patterns hold true in southern latitudes.

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THREE NEW SPECIES OF *TIPORUS* WATTS (COLEOPTERA: DYTISCIDAE) WITH REDESCRIPTIONS OF THE OTHER SPECIES IN THE GENUS.

BY C.H.S. WATTS

Summary

WATTS, C.H.S. (2000). Three new species of *Tiporus* Watts, 1985 (Coleoptera: Dytiscidae) are described and figured: *Tiporus georginae*, *T. lachlani* and *T. moriartyensis*. The original descriptions of the existing species were based on a small number of speciamens. Recent collections have allowed these descriptions to be reviewed and, where necessary, corrected and/or enlarged. A key is given to the 11 known species.

THREE NEW SPECIES OF *TIPORUS* WATTS (COLEOPTERA: DYTISCIDAE) WITH REDESCRIPTIONS OF THE OTHER SPECIES IN THE GENUS

C. H. S. WATTS

WATTS, C. H. S. 2000. Three new species of *Tiporus* (Coleoptera; Dytiscidae) with redescriptions of the other species in the genus. *Records of the South Australian Museum* **33**(2): 89–99.

Three new species of *Tiporus* Watts, 1985 (Coleoptera: Dytiscidae) are described and figured: *Tiporus georginae, T. lachlani* and *T. moriartyensis*. The original descriptions of the existing species were based on a small number of specimens. Recent collections have allowed these descriptions to be reviewed and, where necessary, corrected and/or enlarged. A key is given to the 11 known species.

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The genus *Hypodes* Watts, 1978, later changed due to preoccupation to *Tiporus* Watts, 1985, was erected for a group of small to moderate sized Australian Hydroporini related to *Antiporus* Sharp. Members of *Tiporus* are distributed across coastal Northern Australia where they appear to be restricted to rivers and streams, or to the small pools which form in their beds in the dry season. In these habitats some species, such as *T. undecimmaculatus* and *T. josepheni,* are often abundant.

The genus has not been reviewed since my 1978 paper. Many more specimens are now available, among them the three new species described below. The taxonomy of the genus is based on the males, which have distinctive, species-specific genitalia and secondary sexual characters on the legs. Females are more difficult taxonomically but the additional material has allowed these to be tentatively keyed for the first time. Unfortunately, in the case of *T. josepheni,* I mis-associated the sexes in my original description, which has led to confusion over the identification of this species. The type material of all species except *T. collaris* and *T. undecimmaculatus* has been restudied.

The collections from which specimens were examined are listed under the following abbreviations:

- ANIC Australian National Insect Collection, Canberra
- NTM Northern Territory Museum and Art Gallery, Darwin
- QM Queensland Museum, Brisbane
- SAMA South Australian Museum, Adelaide
- WAM Western Australian Museum, Perth
- QDPIM Queensland Department of Primary Industries, Mareeba

Systematics

The genus *Tiporus* Watts belongs to that section of Australian Hydroporini with pseudotetramerous protarsi and densely rugose/punctate bodies including the legs. It can be distinguished from the other genera in this section, *Antiporus* Sharp and *Sekaliporus* Watts, by the form of the humeral angle of the elytron and the three-segmented protarsi in the male (see Watts 1997 for more details).

Within the genus there are two morphological groupings, one group characterised by: lack of pronotal ridges/grooves, moderate to strong dorsal colour pattern, a tendency for the edge of the elytron to bulge or extend outwards near the tip, protibia of the male with a small tubercle on the outside near the base, and the other group characterised by: pronotal ridges/grooves, dark colouring with only vague reddish patches, edges of the elytron serrated but not extended and the male protibia having a broad spine in the middle or towards the apex on the outside. To what degree these groupings reflect phylogenetic relationships has yet to be determined.

Key to *Tiporus* Watts

1 — Disc of pronotum with a ridge/groove running backwards parallel to and at a little distance from sides; edge of elytron serrated in apical half, never with lateral extension near tip; sides of pronotum dark, at most diffusely lighter in colour 7

— Disc of pronotum smooth, at most with weak ridges; edges of elytron usually smooth but often with rounded or triangular extension near tip; sides of pronotum usually with well-defined light coloured area 2

2 — Female with edge of elytron near apex with large, triangular extension reaching beyond tip of elytron (Fig. 8); male without such an extension, protibia with triangular spine on outside near middle .... *T. josepheni* (Watts)

— Both sexes with elytron with at most a modest bulge near tip or with the tip extended; males with small tubercle on outside of protibia at base 3

3 — Larger (4.5 mm long); postcoxal lines narrow, reaching metathorax; outer metatibial spine in male greatly elongated, about twice the length of the inner (Fig. 12); (female unknown) .... *T. moriartyensis* sp. nov.

— Smaller (< 4.1 mm long); postcoxal lines wide, often poorly defined towards front; outer metatibial spine in male normal, not greatly different in length to inner 4

4 — Female with tip of elytron clearly extended (Fig. 15); edge of pronotum weakly sinuate in front; male with metatibia expanded on inside near apex .... *T. tambreyi* (Watts)

— Tip of elytron not, or only weakly, extended (edge of elytron may be moderately expanded near, but not at, tip); sides of pronotum with only a hint of sinuation; male with normal metatibia 5

5 — Extreme front of elytron considerably narrower than adjacent pronotum, difference > width of mid segments of antenna (Fig. 4): lateral extension to elytron near tip absent or weak (Fig. 4); male with very long dagger-shaped proclaw (Fig. 7) .... *T. georginae* sp. nov.

— Extreme front of elytron only slightly narrower than adjacent pronotum, difference <= width of mid segments of antenna; edge of elytron with moderate bulge near tip; males with either short stout proclaws or with moderately long but thin proclaws (Figs 13, 14) 6

6 — Pronotum weakly ridged at sides; edge of elytra straight immediately prior to it meeting pronotum; male proclaw short, thickened basally (Fig. 13) .... *T. denticularis* (Watts)

— Pronotum smooth; edge of elytra slightly curved immediately prior to it meeting pronotum; male proclaw elongate, thin (Fig. 14) .... *T. centralis* (Watts)

7 — Large (> 5.0 mm long); male proclaw thick (Fig. 2), protibia stout, with basal spine (Fig. 3); apical segment of protarsi large, deeply bifid (Fig. 3); Pilbara region of W.A .... *T. lachlani* sp. nov.

— Smaller (< 5.1 mm long); males not as above 8

8 — Tip of elytron with small but distinct point (except in some *T. alastairi*); elytral serrations usually strong; male protibia with prominent, triangular enlargement in apical half 9

— Tip of elytron rounded; elytral serrations weak; male protibia with small spine/ tubercle on inside close to base .... *T. collaris* (Hope)

9 — Viewed laterally, the edge of elytra curves forward for short distance prior to meeting pronotum; male protibia with large triangular expansion on front edge near apex; male proclaw squat .... *T. alastairi* (Watts)

— Viewed laterally, the edge of elytra not, or only slightly, curved immediately prior to meeting lateral edge of pronotum; male protibia with small triangular expansion on front edge in middle or towards apex; male proclaw thin 10

10 — Male with tip of central lobe of aedeagus pointed (Fig. 20); protibia with triangular expansion just beyond centre .... *T. giuliani* (Watts)

— Male with tip of central lobe of aedeagus broad, weakly tridentate (Fig. 16); protibia with triangular expansion on front edge,

either in middle (N. Qld.) or towards apex (N.T., WA) ....
.... *T. undecimmaculatus* (Clark)

Tiporus georginae sp. nov.

Types

Holotype: male: 'W. Aust. Mitchell Plateau. 14°40'S 125°44'E 23 Sept 1982. B. V. Timms', dissected and mounted on card, SAMA.

Paratypes: 5, "14°52'S 125°50'E WA 'The Crusher' CALM Site 9/1 4 km S by W Mining Camp Mitchell Plateau 2–6 June 1988 I. D. Naumann", ANIC; 4, "14°25'S 126°40'E CALM Site 4/3 14 km S by E Kalumburu Mission W. A. 3–6 June 1988 T. A. Weir", ANIC (3), SAMA (1). All labelled as collected at light in open forest except for one in closed forest at CALM site 4/3.

Description Figs 4–7

Length 3.5 – 4.0 mm. Elongate-oval, wider in middle, front edge of elytron considerably narrower than rear edge of pronotum (Fig. 4). Pronotum smooth, without lateral ridges or grooves; edge of elytron turns forward sharply just before meeting edge of pronotum, very weakly serrate towards rear, usually slightly expanded near but not at tip, quite strongly acuminate. Whole body strongly rugose/punctate. Dorsal surface dark testaceous-black, front margin of head, sides and parts of front and rear margins of pronotum, three lateral spots and often some spots inwards from these on elytron, testaceous. Ventral surface dark testaceous-black, appendages including pro- and mesocoxae, much lighter. Pronotal process narrow, keeled, bluntly pointed. Metacoxal lines relatively close in hind half, widening to a bit more than two times their narrowest width in front quarter.

Male. Protarsi three-segmented, with adhesive setae ventrally, anterior parts of segments expanded, small spine on hind apical corner of second segment, third segment about 2.5 times length of second, single claw extremely long, expanded in middle (Fig. 6). Protibia with small tubercle on anterior edge at base (Fig. 7). Mesotarsi as for female. Metatibia with a slight thickening on inside near apex. Apical ventrite with small, sharp, apical keel/spine. Median lobe of aedeagus broad in centre, very narrow in apical quarter (Fig. 5).

Female. Protarsi five-segmented, first three moderately expanded with adhesive setae ventrally, apical segment cylindrical. Mesotarsi much narrower.

Remarks

Resembling *T. centralis* and *T. denticularis* in size and colour but with the mis-match of the humeral angle of the elytron and the posterolateral angle of the pronotum more noticeable (Fig. 4). Some specimens of *T. centralis* have this feature to a degree but the extremely long, dagger-like male proclaw in *T. georginae* (Figs 6, 7) readily separates male specimens from this and other *Tiporus*. The aedeagus is distinctive (Fig. 5). The species is known only from the Kimberley region where it is broadly sympatric with *T. centralis*.

Distribution

The Kimberley region of Western Australia.

Tiporus moriartyensis sp. nov.

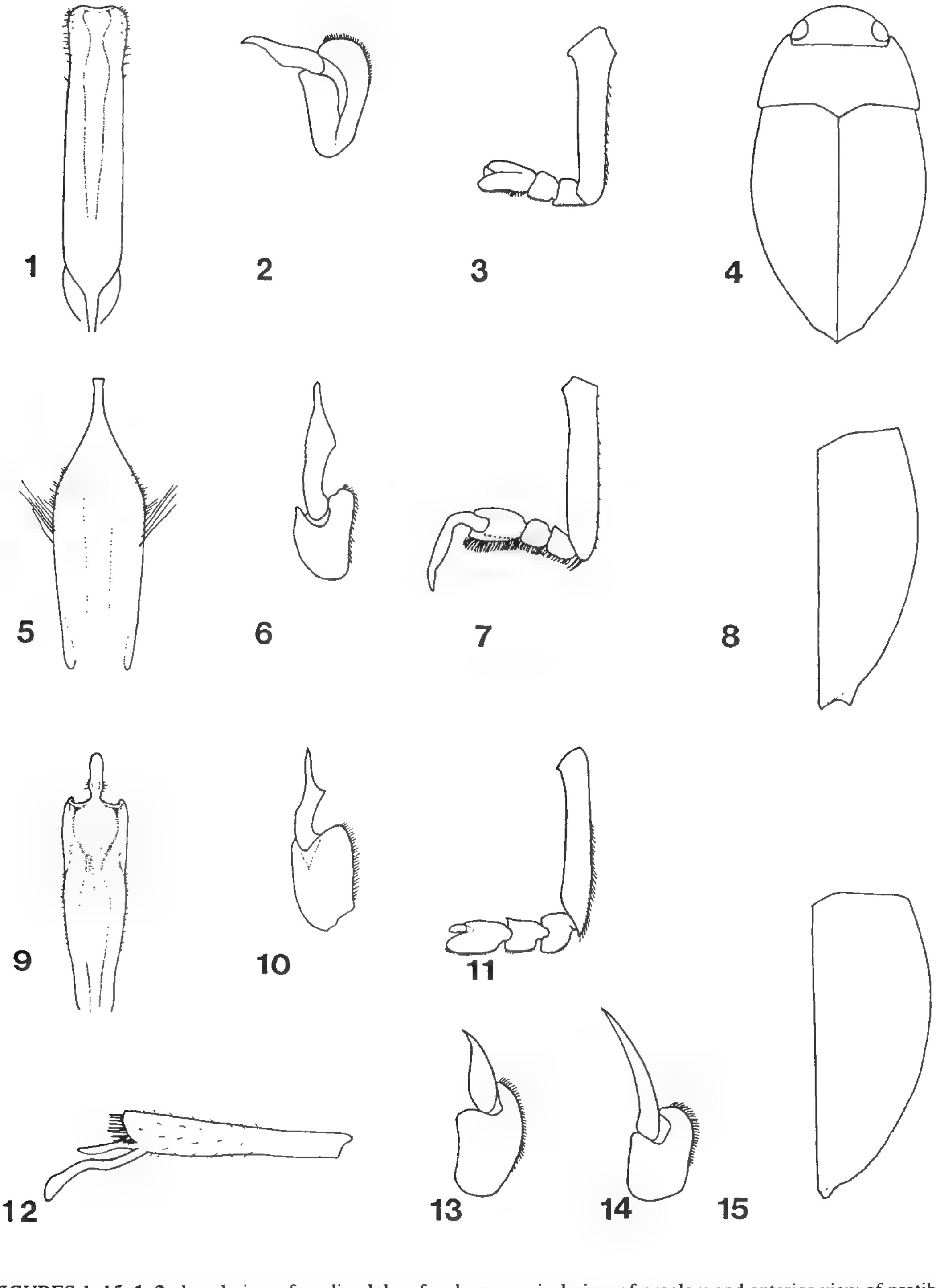
Types

Holotype: male, 'Moriarty ck N.T. Reardon 8/82', SAMA.

Description Figs 9–12

Length 4.5 mm. Elongate-oval, widest in middle. Pronotum narrower than elytra. Dorsal surface dark brown-black, rear of head, lateral margins and rear margin of pronotum, three small lateral spots and two larger spots near suture on elytron testaceous. Ventral surface mottled dark and light testaceous, appendages including pro- and mesocoxae much lighter. Whole body covered with rugose punctures, punctures smaller and less rugose than in other *Tiporus* species. Disc of pronotum smooth, without lateral ridges or grooves. Side of elytron curves forward immediately before meeting edge of pronotum, very weakly serrate towards tip, apex obliquely truncated. Pronotal process relatively broad, keeled, tip blunt. Metacoxal lines close, diverging to about two times their minimum width towards front, reaching mesosternum.

Male. Protarsi three segmented, segments expanded in front, with dense adhesive setae ventrally, second segment with small tooth on hind margin, apical segment 2.5 times length of second; claw short, rapidly narrowing to about half its width in middle (Fig. 10). Protibia with weak tubercle/spine near base on anterior edge. Metatibia with inner apical spine, twisted, flattened and broadened slightly at tip, about two



FIGURES 1–15. **1–3**, dorsal view of median lobe of aedeagus, apical view of proclaw and anterior view of protibia and tarsi of *T. lachlani*; **5–7**, ditto *T. georginae*; **9–11**, ditto *T. moriartyensis*; **4**, dorsal outline of *T. georginae*; **8**, dorsal outline of elytron of *T. josepheni*; **12**, metafemur of *T. moriartyensis*; **13**, apical view of proclaw and third tarsal segment of *T. denticulatus*; **14,** ditto *T. centralis*; **15**, dorsal outline of elytron of *T. tambreyi*.

times length of outer, which is simple (Fig. 12). Apex of last abdominal ventrite broadly depressed in middle, rear edge with two small spines in middle. Median lobe of aedeagus broad in middle, abruptly narrowing near apex (Fig. 9).

Female. Not known.

Remarks

Although only one specimen is available this is enough to show that *T. moriartyensis* is a very distinctive species. It belongs to the group of species lacking lateral pronotal ridges but is noticeably larger and less strongly punctured than other members. No other *Tiporus* has the inner apical spine on the metatibia modified as in this species. The female is unknown but it is likely that this character is restricted to the male.

Distribution

Known only from the type locality—Moriarty Creek, 160°4'S 129°12'E—in the Northern Territory.

Tiporus lachlani sp. nov.

Types

Holotype: male, 'Wooramel R. WA 25°47.52'S 115°17.44'E 26.8.94 S.A. Halse', SAMA.

Paratypes: 1, female, as for holotype, SAMA; 1, male, 'Gregory Gorge Fortescue R W.A. 2 xii.74 coll. K. F. Walker', SAMA.

Description Figs 1–3

Length 5.6 mm. Elongate-oval, widest behind middle, outline strongly indented at junction of pronotum and elytra. Lateral edge of elytra not curved forward immediately prior to meeting pronotum. Pronotum with well-developed lateral ridge/groove on each side, edge of elytron weakly serrated towards tip, tip weakly pointed. Dark testaceous, rear edge of head, lateral edges of pronotum, small patches at side of elytron near apex and appendages slightly lighter. Densely rugose/punctate throughout. Pronotal process narrow, keeled, bluntly pointed. Metacoxal lines raised, relatively wide apart, strongly diverging in anterior half to about 2.5 times their narrowest width, raised lines not reaching metasternum. Epipleuron evenly narrows until close to apex where it abruptly ends.

Male. Protarsi three-segmented, anterior portions greatly expanded and densely covered with adhesive setae ventrally, third segment as long as first two; claw shorter than third segment, squat, broad but narrowing to sharp point (Figs 2, 3). Protibia relatively short, thick, with strong tubercle on outside at base (Fig. 3). Apical ventrite with short well-marked keel near apex. Median lobe of aedeagus relatively narrow, parallel-sided (Fig. 1), ending in pick-like beak (not visible dorsally).

Female. Protarsi five-segmented, first three segments weakly expanded anteriorly, densely covered with adhesive setae ventrally, fourth segment very small, apical segment thin, cylindrical, shorter than third. Inner apical edge of metatarsal segments extended, extension accentuated by a number of strong spines.

Remarks

Tiporus lachlani differs from other *Tiporus* with ridged/grooved pronotum by its large size and strongly narrowed pronotal-elytral junction, as well as in male characters.

Distribution

The Pilbara/Gascoyne region of Western Australia.

Redescriptions Of The Other Species In The Genus, After Watts (1978) (Listed In Alphabetical Order)

Tiporus alastairi (Watts, 1978)

Description Fig. 23

Length 4.0 – 5.2 mm. Oval, convex. Dark red-brown, underside lighter. Strongly and densely rugose-punctate all over. Pronotum with a distinct raised ridge parallel to and a little distance inwards from each side, area just inside ridge depressed, ridge and depression strongest anteriorly, weak posteriorly. Elytron weakly margined, weakly serrated towards apex, usually sharply pointed (rounded in male holotype). Edge of elytron curves forward for short distance immediately prior to meeting edge of pronotum. Prothoracic process narrow, strongly convex, roundly pointed at apex, only slightly constricted between procoxae. Metacoxal lines strongly raised, well separated, quite strongly diverging in anterior two-thirds, not quite reaching mesosternum.

Male. Protarsus three-segmented. Anterior sides of segments of protarsus moderately expanded, a little expanded on mesotarsus. Single claw on protarsus short, broad, weakly curved, dorsoventrally flattened, anterior edge deeply notched just beyond middle. Protibia with a large sharp tooth on outside just anterior to middle. Apical sternite strongly carinate for a short distance in middle near apex. See Fig. 23 for aedeagus.

Female. Protarsus five-segmented. Anterior sides of pro-and mesotarsi less expanded than in male. Apical abdominal sternite with a short sharp ridge in middle near apex.

Remarks

Females are difficult to separate from those of *T. undecimmaculatus* or *T. giuliani* but are larger than most specimens of these species and the edge of the elytron curves forward for a short distance immediately before it meets the edge of the pronotum whereas it is straight or almost so in *T. giuliani* and *T. undecimmaculatus*. The same applies to the males but in addition these have a much shorter and broader proclaw and a much narrower central lobe to the aedeagus than in these species. The species is so far known only from the north of Western Australia.

Distribution

Western Australia

2, Derby, SAMA; 3, 4 km W King Cascade, 15°38S 125°15'E, ANIC; 1, Kings Sound, ANIC.

Tiporus centralis (Watts, 1978)

Description Fig. 24

Length 3.2 – 3.9 mm. Oval, convex. Black; sides of pronotum and appendages reddish, sides and portions of middle of pronotum and base of elytron with vague red patches. Strongly and densely rugose-punctate throughout. Reticulate. Pronotum not flanged. Elytron with a weak shallow stria near the suture, edge curves forward slightly immediately before meeting pronotum, edge weakly to moderately expanded for a short distance near, but not at, tip which is pointed. Prothoracic process narrow, ridged in midline, apex rounded, weakly constricted between procoxae. Metacoxal lines strongly raised to metasternum, quite strongly divergent in anterior two-thirds.

Male. Protarsus three-segmented. Anterior sides of segments of protarsus moderately expanded, mesotarsus slightly expanded. Single claw on protarsus long, sharply curved near base, apical two-thirds straight. Protibia with a small tooth on outside near base. Tip of apical abdominal sternite broadly grooved in midline. See Fig. 24 for aedeagus

Female. Protarsi five-segmented; basal three segments of roughly similar size, weakly expanded anteriorly, ventral surface covered in adhesive setae; fourth segment very small; apical segment narrow, cylindrical, about same length as third segment; claws weakly developed.

Remarks

Tiporus centralis is very similar to *T. denticularis* and *T. georginae*—see discussion under those species.

Originally known only from the male holotype, the species is now known to be reasonably common in the Northern Territory and into Western Australia. It seems to have a more inland distribution than either *T. collaris* or *T. undecimmaculatus*, the other common Northern Territory species.

Distribution

Northern Territory

2, 46 km SSW Borroloola, ANIC; 1, 48 km SW by S Borroloola, ANIC; 3, 45 km W Borroloola, SAMA; 1, Davenport Ranges, 40 km NE Murray Downs Station, SAMA; 1, Elkedra Homestead, NTM; 6, Gosse River, Murchison Ranges, NTM; 2, Kakadu Highway, 31 km from Pine Creek, SAMA; 1, 35 mi N Larrimah, SAMA; 2, Moriarty Creek, SAMA; 1, Skull Creek (Victoria River), SAMA; 10, Victoria River, SAMA.

Western Australia

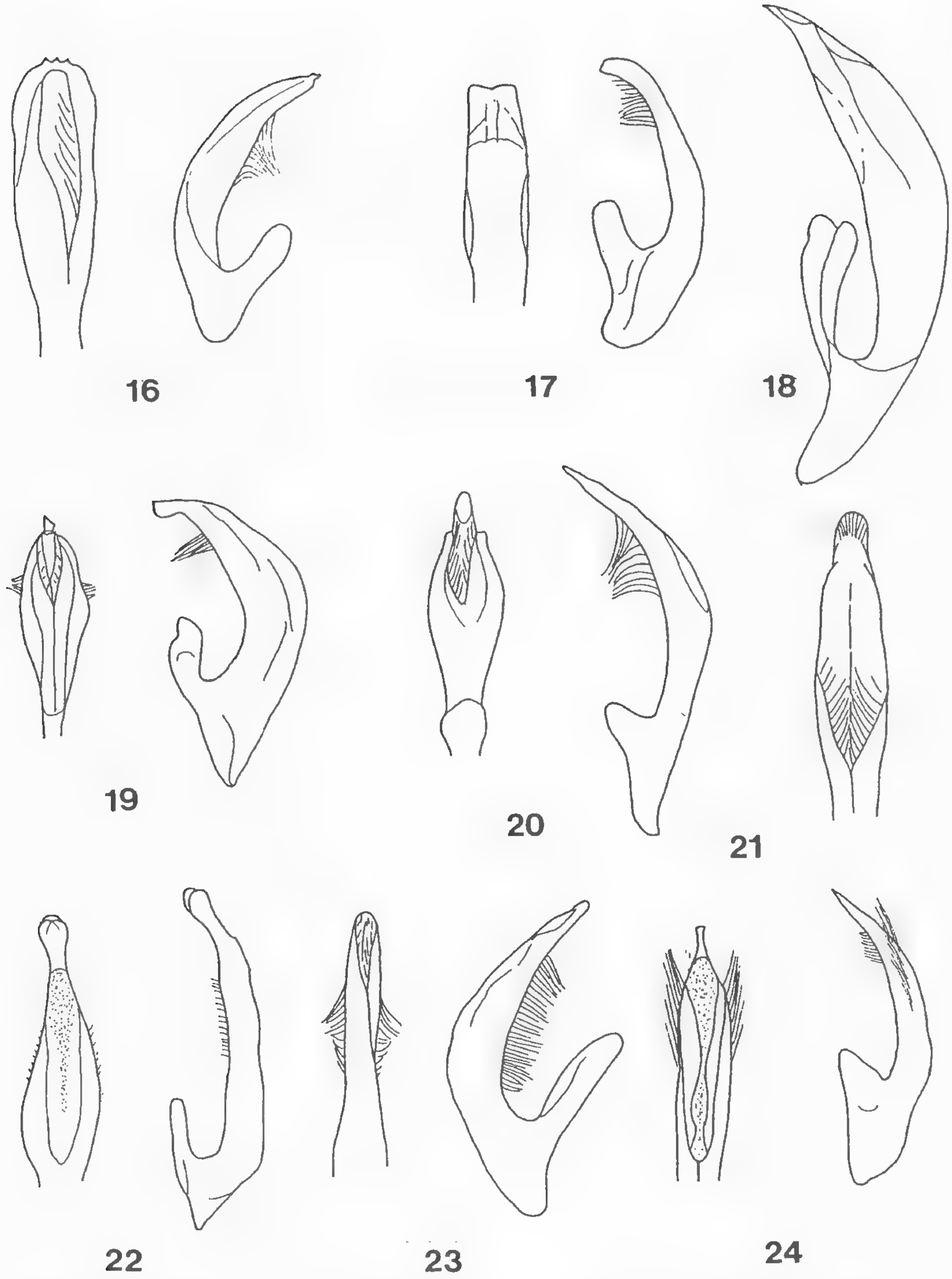
1, Stumpy Creek 'Glenroy', 16°55'S 125°34'E, SAMA.

Tiporus collaris (Hope, 1842)

Description Figs 18, 21

Length 3.3 – 4.1 mm. Oval, convex. Black; undersides and appendages a little lighter. Strongly and densely rugose-punctate all over. Reticulate. Pronotum widely flanged at sides, lacking raised ridges between disc and flange except very slightly anteriorly. Elytron weakly margined, moderately serrate towards apex which is rounded, base with vague longitudinal impressions. Prothoracic process narrow, strongly convex, roundly pointed at apex, not constricted between procoxae. Metacoxal lines raised, slightly to moderately diverging anteriorly.

Male. Protarsus three-segmented. Anterior sides



FIGURES 16–24. **16,** dorsal and lateral views of median lobe of aedeagus of *T. undecimmaculatus*; **17,** ditto *T. tambreyi*; **18,** ditto (lateral view) *T. collaris* (holotype); **19,** ditto *T. josepheni*; **20,** ditto *T. giuliani*; **21,** ditto (dorsal view) *T. collaris* (holotype); **22,** ditto *T. denticularis*; **23,** ditto *T. alastairi*; **24,** ditto *T. centralis*. From Watts (1978).

of segments of protarsus moderately expanded, those on mesotarsus a little expanded. Single claw on protarsus thick and curved, strongly toothed on underside near base. Protibia with a small tooth on outside near base. Tip of apical abdominal sternite moderately tuberculate in middle. See Figs 18, 21 for aedeagus.

Female. Protarsus five-segmented. Anterior sides of segments of protarsus a little less expanded than in male. Protarsus with two simple claws. Apical abdominal sternite simple.

Remarks

Tiporus collaris is very similar to *T. giuliani* and to *T. undecimmaculatus.* Males are readily distinguished from both these species by the basal position of the tubercle on the protibia rather than the central or more apical position in *T. giuliani* and *T. undecimmaculatus.* In addition, *T. collaris* is slightly more rounded, has slightly weaker pronotal ridges/grooves and has rounded rather than sharply pointed tips to the elytra.

The species occurs in small temporary streams in stony country across the north of the Northern Territory and Western Australia. Like *T. undecimmaculatus*, with which it is often collected, it appears to be more coastal than *T. centralis.*

Distribution

Northern Territory

8, 5 km SE Mt Borradaile, SAMA; 4, 6 km SE Mt Borradaile, SAMA; 1, 19 km E by S Mt Borradaile, ANIC; 1, Canon Hill, Kakadu National Park, SAMA; 1, Cooper Creek near Mt Borradaile, SAMA; 17, 1 km W Gubara, Kakadu National Park, SAMA; 1, 20 km SSW Jabiru, SAMA; 1, Kambolgie Creek, SAMA; 4, 10 km E by N Mt Cahill, ANIC; 1, Nawurlandja, Kakadu National Park, SAMA; 1, 6 km SW by S Oenpelli, SAMA.

Western Australia

1, Carson Escarpment, 14°49'S 126°49'E, ANIC; 1, Drysdale River, 15°02'S 126°55'E, ANIC; 2, Kimberley, SAMA; 4, Mitchell Plateau, 14°40'S 125°44'E, SAMA; 1, Upper Camp Creek, 14°49'S 125°51'E, SAMA.

Tiporus denticulatus (Watts, 1978)

Description Fig. 22

Length 3.4 – 3.6 mm. Oval, convex. Dark red-brown; sides, base and portions of anterior of pronotum, some small patches on elytron and appendages yellowish. Strongly and densely rugose-punctate throughout. Pronotum not flanged, with a weak ridge with deep groove on inside, parallel to and some distance inwards from sides. Apex of elytron pointed. Epipleuron with a small triangular expansion just before apex. Prothoracic process relatively broad, ridged in midline, apex rounded, moderately constricted between procoxae. Metacoxal lines straight in posterior half, rapidly diverging in anterior half, not reaching metasternum.

Male. Protarsus three-segmented. Anterior sides of segments of protarsus moderately expanded. Mesotarsus a little expanded. Single claw on protarsus short, flat, spindle-shaped, rapidly narrowing near apex on inside. Protibia with small tooth on outside near base. Tip of apical sternite with small weak ridge in midline. See Fig. 22 for aedeagus.

Female. Protarsus five-segmented, basal segments somewhat expanded on inside.

Remarks

Although the species has a weak ridge/groove on the side of the pronotum, the testaceous margin of the pronotum, smooth elytron edge, lateral expansion of the epipleuron near the tip and the basal position of the tubercle on the male protibia, ally it to the *T. josepheni* group of species. *Tiporus denticularis* is very similar to *T. centralis* and females are difficult to separate, but they differ from this species by the greater development of the pronotal ridge/groove and by the extreme front edge of the elytron immediately before it meets the edge of the pronotum being slightly curved in *T. centralis* but straight in *T. denticularis.*

Originally only known from the Cairns-Cooktown region of North Queensland the additional specimens extend its known range into the Northern Territory.

Distribution

Queensland

1, 34 km NW Chillagoe, SAMA; 8, 70 km SW Greenvale, SAMA; 7, Lakeland Downs, SAMA; 3, Laura, SAMA; 4, Mary Creek, 16°33'S 12°5'E, ANIC; 2, 11 km WSW Petford, QDPIM; 2, Walsh River near Chillagoe, QDPIM; 1, Windsor Tableland, QDPIM.

Northern Territory

1, Bullita Outstation, 16°07'S 130°25'E, NTM; 1, Victoria River, SAMA.

Tiporus giuliani (Watts, 1978)

Description Fig. 20

Length 3.6 – 4.2 mm. Oval, convex. Black; appendages, some vague reddish areas at base of pronotum and base and sides of elytron, lighter. Moderately strongly rugose-punctate throughout. Pronotum with a raised ridge parallel to and a little distant inwards from each side, area just inside ridge depressed, ridge and depression strongest anteriorly, weak posteriorly. Elytron weakly serrated towards apex which is pointed. Prothoracic process narrow, strongly convex, bluntly pointed at apex, only slightly constricted between procoxae. Metacoxal lines relatively close, strongly diverging in central third, weakly in anterior and posterior third, reaching metasternum.

Male. Protarsus three-segmented. Anterior sides of segments of protarsus moderately expanded, weakly so on mesotarsus. Single claw on protarsus short, narrow, with slight notch on underside in middle. Protibia moderately strongly toothed on outside in middle. Apical sternite strongly carinate for a short distance in middle near apex. See Fig. 20 for aedeagus.

Female. Protarsus five-segmented. Pro- and mesotarsi less expanded than in male. Apical abdominal sternite very weakly carinate in middle near apex.

Remarks

Tiporus giuliani is close to *T. undecimmaculatus* and *T. collaris*. It can be separated from *T. collaris* by its stronger pronotal ridges/grooves, sharply pointed elytral tips, stronger colour pattern and the central position of the spine on the male protibia.

The only clear separation from *T. undecimmaculatus* is the shape of the tip of the median lobe of the aedeagus which is broad with three small spines at the tip in *T. undecimmaculatus* (Fig. 16) and narrow and bluntly pointed in *T. giuliani* (Fig. 20). In the Northern Territory and Western Australia the more apical position of the spine on the male protibia and the more pronounced dorsal colour pattern will separate it from *T. undecimmaculatus.* However specimens of *T. undecimmaculatus* from Queensland resemble *T. giuliani* both in the central position of the spine on the male protibia and in the well developed dorsal colour pattern.

A less common species than some and possibly more inland than coastal in distribution.

Distribution

Northern Territory

4, Kakadu Highway, 31 km from Pine Creek, SAMA.

Western Australia

1, Beverley Springs, WAM; 2, Duncan Highway, WAM; 2, near Dampier Downs, WAM; 4, Logues Springs, 102 km SE by E Broome, ANIC; 1, 163 km SE by S Broome, ANIC.

Tiporus josepheni (Watts, 1978).

Description Figs 8, 19

Length 3.5 – 4.1 mm. Oval, convex. Black, sides of pronotum narrowly vaguely reddish, appendages dark red-brown. Ventral surface moderately and densely rugose-punctate, dorsal surface closely and moderately punctate. Pronotum not laterally flanged or ridged. Tip of elytron weakly pointed. Prothoracic process narrow, strongly convex, only slightly constricted between procoxae, apex rounded, midline virtually impunctate. Metacoxal lines well separated, moderately diverging posteriorly and in middle, subparallel in anterior quarter, reaching metasternum.

Male. Protarsus three-segmented. Anterior sides of segments of protarsus strongly expanded. Mesotarsus a little expanded. Single claw on protarsus short, flat, narrowing abruptly on inside near apex, base with a large rounded expansion beneath. Protibia with small tooth on outside in middle. Tip of apical sternite depressed slightly in midline. See Fig. 19 for aedeagus.

Female. Protarsus five-segmented, robust, basal segments somewhat expanded on inside. Elytron with very well developed lateral subapical spine (Fig. 8).

Remarks

Originally described from Beverley Springs and Wittenoom Gorge in the Kimberley and Pilbarra regions of Western Australia respectively, the species is now known to be much more widespread, occurring right across coastal Northern Australia. It is particularly common in North Queensland. It seems to favour larger and more permanent rivers than other *Tiporus.*

Unfortunately I mis-associated the sexes in my original description. (The female paratype in ANIC belongs to *T. tambreyi.*)

Distribution

Northern Territory

2, Cooper Creek near Mt Borradaile, SAMA; 7, Magela Creek, SAMA; 2, Magela Creek, 12 km E Jabiru, SAMA; 1, Nourlangie Creek, 20 km SSW Jabiru, SAMA.

Queensland

1, Barron River, QDPIM; 52, 8 km N Bluewater, SAMA; 1, 25 km N Coen, SAMA; 2, 2 km NW Daintree, QDPIM; 2, Emu Creek 5 km W Petford, QDPIM; 8, Eubenangee Swamp near Babinda, SAMA; 2, Helenvale, SAMA; 18, Lakeland Downs, SAMA; 1, Laura, SAMA; 2, Mazlin Creek Atherton area, QDPIM; 1, 2 km S Mt Molloy, SAMA; 2, 20 km S Townsville, SAMA; 1, 37 km S Townsville, SAMA; 7, Walsh River 34 km NW Chillagoe, SAMA.

Western Australia

1, Beverley Springs, WAM; 1, Stumpy Creek 'Glenroy' 16°55'S 125°34'E, SAMA.

Tiporus tambreyi (Watts, 1978)

Description Fig. 17

Length 3.5 – 4.4 mm. Oblong oval, strongly convex, pronotum a little constricted in anterior quarter. Black, extreme anterior of head, sides of pronotum narrowly, a basal spot and extreme lateral markings on elytron and appendages reddish. Moderately strongly and very densely punctate all over, punctures on pronotum and elytron with short setae. Reticulation strongest anteriorly. Pronotum and elytron weakly margined, margins of elytron weakly serrated towards apex, extreme apex not margined. Prothoracic process lanceolate, quite strongly expanded behind procoxae, narrow between procoxae, weakly flanged, strongly carinate. Metacoxal lines strongly raised, rapidly diverging in anterior half, subparallel posteriorly.

Male. Anterior sides of segments of protarsus moderately expanded, posterior sides unexpanded. Basal segment of mesotarsus weakly expanded. Single claw of protarsus greatly expanded in basal half, flattened dorsoventrally. Metafemur robust, curved. Metatibia angularly thickened on inside near apex. Protibia with a small tooth on outside close to base. Last abdominal sternite widely and weakly grooved in midline with a small knob in middle of groove at extreme apex, edges of sternite at apex raised for some distance either side of groove. See Fig.17 for aedeagus.

Female. Smaller, more densely punctate. Protarsus asymmetrically expanded as in male but not to same extent. With small triangular extension at tip of elytron, diverging from each other when elytra closed (Fig. 15).

Remarks

A relatively large species known only from the Pilbara region of Western Australia, readily distinguished from all other *Tiporus* by the expanded male metatibia and the triangularly extended elytral tips in the female. The sides of the pronotum straighten slightly in front giving the pronotum a slightly sinuate outline.

Distribution

Western Australia

1, 17 km N by E Cane River Homestead, ANIC; 15, Gregory Gorge, Fortescue River, SAMA; 16, Millstream, ANIC; 1, Millstream, Palm Pool area, WAM; 9, 1 km N Millstream, ANIC; 4, 3 km NW by W Millstream, ANIC; 1, Tambrey, WAM; 1, Wittenoom Gorge, ANIC.

Tiporus undecimmaculatus (Clark, 1862)

Description Fig. 16

Length 3.4 – 4.6 mm. Oval, convex. Black or dark red-brown; underside and appendages a little lighter, base of pronotum and sides of elytron with vague red patches in many. Strongly and densely rugose-punctate all over. Reticulate. Pronotum with a distinct raised ridge parallel to and a little distance from each side, area just inside ridge depressed, ridge and depression strongest anteriorly, weak posteriorly. Elytron weakly margined, strongly convex, rounded towards apex which is pointed. Prothoracic process narrow, strongly convex, roundly pointed at apex, little if at all constricted between procoxae. Metacoxal lines raised, slightly to moderately diverging anteriorly.

Male. Anterior sides of segments of protarsus moderately expanded, those on mesotarsus a little expanded. Single claw on protarsus weakly curved, slightly thickened and with a small tooth on underside near base and another just before the middle. Protibia with a small sharp tooth on outside in apical half. Tip of apical abdominal sternite weakly to strongly tuberculate in middle. See Fig. 16 for aedeagus.

Female. Anterior sides of segments of protarsus a little less expanded than in the male. Protarsus with two simple claws. Apical abdominal sternite simple or slightly tuberculate at tip.

Remarks

Tiporus undecimmaculatus is a widespread and variable species very similar to *T. collaris* and *T. giuliani*—see notes under those species. Two forms are distinguishable. The nominal form, from the Northern Territory and Western Australia, is usually dark with the dorsal colour pattern subdued or absent and has the spine on the male protibia towards the apex. The other form, from north Queensland, has a well-developed dorsal colour pattern, the spine on the male protibia close to the centre of the protibia, the central lobe of the aedeagus a bit broader and also tends to be larger.

Tiporus undecimmaculatus is common in small temporary streams in stony country in coastal areas across Northern Australia in similar habitats to *T. collaris* but is usually more abundant than that species. A more coastal species than *T. centralis*.

Distribution

Western Australia

1, Bigge Island, 14°29'S 125°10'E. SAMA; 7, Careening Bay, 15°06S 125°00E, SAMA; 9, Carson Escarpment, 14°49'S 126°49'E, ANIC; 1, Cave Spring, 15°32'S 128°50'E, WAM, ANIC; 1, Duncan Highway, WAM; 3, 14 km S by E Kalumburu Mission, ANIC; 2, 4 km W King Cascade, 15°38'S 125°15'E, ANIC; 3, 4 km S by W Mining Camp, Mitchell Plateau, 14°52'S 125°50'E, ANIC; 7, Mitchell Plateau, 14°40'S 12°44'E, SAMA.

Northern Territory

3, 6 km SE Mt Borradaile, SAMA; 6, 19 km E by S Mt Borradaile, ANIC, NTM; 137, 5 km SE Mt Borradaile, SAMA; 2, Bukkita outstation, 16°07'S 130°25'E, NTM; 1, 7 km NW by N Cahills Crossing, Kakadu National Park, SAMA; 1, Canon Hill, Kakadu National Park, SAMA; 1, 4 mi S Coolibah, WAM; 3, Gosse River, Murchison Ranges, NTM; 13, 1 km W Gubara, Kakadu National Park, SAMA; 2, Kambolgie Creek, SAMA; 2, Magela Creek, SAMA; 2, 19 km E by N Mt Cahill, ANIC; 5, 10 km E by N Mt Cahill, ANIC; 1, 15 km E by N Mt Cahill, ANIC; 15, 40 km NE Murray Downs Station, SAMA; 4, 6 km SW by S Oenpelli, ANIC, SAMA; 5, Nawurlandja, Kakadu National Park, SAMA; 1, Nourlangie Creek, 20 km S Jabiru SAMA.

Queensland

2, Cairns, SAMA; 1, Charters Towers, SAMA; 1, 25 km N Coen, SAMA; 1, Helenvale, SAMA; 15, 14 km W Herberton, SAMA; 21, Lakeland Downs, SAMA; 4, Laura, SAMA; 1, 12 km N Laura, SAMA; 1, McIlwraith Ranges Weather Station, SAMA; 1, 17 km up Mt Lewis Road, QDPIM; 6, Mt Spec, ANIC; 8, 10 mi W Paluma, SAMA; 1, 20 km W Petford, SAMA; 8, 15 km W Petford, QDPIM.

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The curators of the collections listed earlier are thanked for allowing me to examine specimens in their care. The illustrations were most ably done by Mr R. Gutteridge and Ms Debbie Churches helped finalise the manuscript. All are thanked for their support and help.

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THE *PARACYMUS* OF AUSTRALIA (COLEOPTERA, HYDROPHILIDAE).

BY ELIO GENTILI

Summary

GENTILI, E. (2000). The described Australian *Paracymus* were hitherto placed in six species. Of these three are to be considered synonyms of *P. pygmaeus* (MacLeay, 1871): *nitidiusculus* (Broun, 1880), *metallescens* Fauvel, 1883, and *desolatus* Woolridge, 1976 (new synonymy). To the remaining valid species *P. pygmaeus* (MacLeay, 1871), *spenceri* Blackburn, 1896, and *gigas* Gentili, 1996 another six new species are now added: *P. cariceti, wattsi, opasus, australiae, weiri,* and *ovum*. Lectotypes are designated for *P. pygmaeus, nitidiusculus,* and *metallescens*. Each valid species is described, discussed, mapped (with a detailed list of localities), figured (aedeagi, outlines) and keyed.

THE *PARACYMUS* OF AUSTRALIA (COLEOPTERA, HYDROPHILIDAE)

ELIO GENTILI

GENTILI, E. 2000. The *Paracymus* of Australia (Coleoptera, Hydrophilidae). *Records of the South Australian Museum* **33**(2): 101–122.

The described Australian *Paracymus* were hitherto placed in six species. Of these three are to be considered synonyms of *P. pygmaeus* (MacLeay, 1871): *nitidiusculus* (Broun, 1880), *metallescens* Fauvel, 1883, and *desolatus* Wooldridge, 1976 (new synonymy). To the remaining valid species *P. pygmaeus* (MacLeay, 1871), *spenceri* Blackburn, 1896, and *gigas* Gentili, 1996 another six new species are now added: *P. cariceti, wattsi, opacus, australiae, weiri,* and *ovum.* Lectotypes are designated for *P. pygmaeus, nitidiusculus,* and *metallescens.* Each valid species is described, discussed, mapped (with a detailed list of localities), figured (aedeagi, outlines) and keyed.

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Introduction

This work is intended to continue on with the project of A. F. Newton and M. K. Thayer to improve our knowledge of the Staphyliniformia of Australia. After the studies on the hydrophilid genera *Notohydrus* (Gentili 1992) and *Paranacaena* (Gentili 1993) the genus *Paracymus* Thomson, 1867 is now considered.

Hansen (1991) placed *Paracymus* in the tribe Anacaenini, giving a description of the genus. The features basically characterising *Paracymus* among Anacaenini appear to be the prosternum longitudinally carinate and the presence of a sutural stria on the elytra (see also d'Orchymont 1942).

Gentili (1993) dealt with the nine Australian taxa treated in the literature under the genus *Paracymus*, placing four of them (*lindi* Blackburn, 1888, *sublineatus* Blackburn, 1888, *horni* Blackburn, 1896, and *eremita* Blackburn, 1896) in *Paranacaena* Blackburn, 1888 and one (*nigerrimus* Blackburn, 1891) in *Chaetarthria* Stephens, 1835, leaving in *Paracymus* the remaining four (*pygmaeus* McLeay, 1871, *nitidiusculus* Broun, 1880, *spenceri* Blackburn, 1896, and *desolatus* Wooldridge, 1976). Four other taxa might be added to the list: *Paracymus phalacroides* (Wollaston, 1867); Wooldridge 1978 wrote: 'two females from Australia seem to belong here. If these...specimens are really *P. phalacroides*, they probably are the result of accidental introduction, because they do not seem to be established in...the country'; *Paracymus metallescens* Fauvel, 1883 from New Caledonia; *Anacaena tepida* Winterbourn, 1970 treated as *Paracymus* in a manuscript of R. Ordish on New Zealand Hydrophilidae, and *Paracymus gigas* Gentili, 1996.

Material And Methods

More than 6 000 specimens were studied from the Institutes and Museums listed below under 'Acronyms', nearly 5 000 of them belonging to the Australian National Insect Collection. Specimens were examined with a Beck Kassel CBS stereoscopic microscope; the figured aedeagi were mounted in di-methyl-hydanthoin-formaldehyde (DMHF) on transparent plastic card, studied and drawn with a GALILEO LG transmitted light microscope equipped with a projection device.

Acronyms

- AMS – Australian Museum, Sydney.
- ANIC – Australian National Insect Collection, CSIRO, Canberra.
- CASF – California Academy of Sciences, San Francisco.
- FMNH – Field Museum Natural History, Chicago.
- ISNB – Institut Royal des Sciences Naturelles de Belgique, Bruxelles.
- MSNV – Museo Civico di Storia Naturale, Verona.
- NHML – Natural History Museum, London.
- NMW – Naturhistorisches Museum, Wien.
- SAMA – South Australian Museum, Adelaide.
- USNM – United States National Museum, Washington.

Descriptions

Each valid Australian species is discussed below according to the following scheme: (1) References; the dates of description and of the quoted papers conform to Hansen (1999). (2) Type material; I searched for the available types of the described taxa (valid species and synonyms), designating lectotypes and paralectotypes where necessary. (3) Description; many characters are considered: measures, outline, upperside, underside, palps, antennae, legs and aedeagus. (4) Discussion; the species are compared with other similar species or with the proposed synonyms. (5) Material examined; the States of the Australian continent are listed alphabetically; the localities within each State are also listed alphabetically. (6) Biology; the biological notes are derived from the label data.

1. *Paracymus pygmaeus* (MacLeay, 1871)

Cyclonotum pygmaeum MacLeay, 1871: 133; White in Masters, 1871: 5.

Coelostoma pygmaeum (MacLeay): Zaitzev 1908, 404.

Paracymus pygmaeus (MacLeay): Blackburn 1888: 820; 1894: 203; Knisch 1924: 167; d'Orchymont 1937: 154, 157; McKeown 1948: 99; Wooldridge 1976: 459–461; Matthews 1982: 55; Hansen 1999: 113.

Hydrobius nitidiusculus Broun, 1880: 78.

Paracymus nitidiusculus (Broun): Sharp 1884: 467; Blackburn 1888: 820–821.

Paracymus metallescens Fauvel, 1883: 352; Knisch 1924: 166; d'Orchymont 1926: 376 (? synonym of *pygmaeus*).

Paracymus desolatus Wooldridge, 1976: 458–459; Hansen 1999: 110. New synonymy.

Types

Lectotype male (1.7 x 1.3 mm): **Queensland**: Gayndah, W. McLeay, 1871, ANIC. A single pin bears the following cards or labels: 1. insect and its abdomen; 2. aedeagus and spiculum gastrale in DMHF; 3. Round amaranth label; 4. Gayndah; 5. Cyclonotum pygmaeum, Macl. Gayndah (by hand); 6. On permanent loan from Macleay Museum University of Sydney; 7. Syntype (red label); 8. Lectotype male designated by E. Gentili 1991 (red label); 9. Lectotype male Cyclonotum pygmaeus Macl. Det. R. G. Ordish. *Paralectotypes*: **Queensland**: Gayndah, W. McLeay 1871 (4), ANIC, AMS. The previously mentioned manuscript of R. G. Ordish says: 'For access to syntypes I am indebted to Mr T. A. Weir, CSIRO Canberra and to Dr G. A. Holloway of the Australian Museum, Sydney. I am advised that the material collected from Gayndah was shared between the Macleay Museum and the Australian Museum and that a specimen in the latter has subsequently been labelled as the Holotype, seemingly on the basis of an original name label (McKeown 1948). As the writer points out, 'types in the Macleay Museum collection are not specially indicated as such'. Validity aside, there are two obstacles to this recognition of a holotype. Firstly, all three mounts bear original determination labels in Macleay's hand, and secondly the mount bearing the holotype label (K 19573) has two specimens on it. There are five syntypes from which a subsequent author could choose a lectotype and I have done this by selecting the best preserved male'. The manuscript of Ordish was not published, but his work is so reliable that I follow his statements, designating as lectotype the specimen chosen by him, seen also by me by courtesy of T. A. Weir.

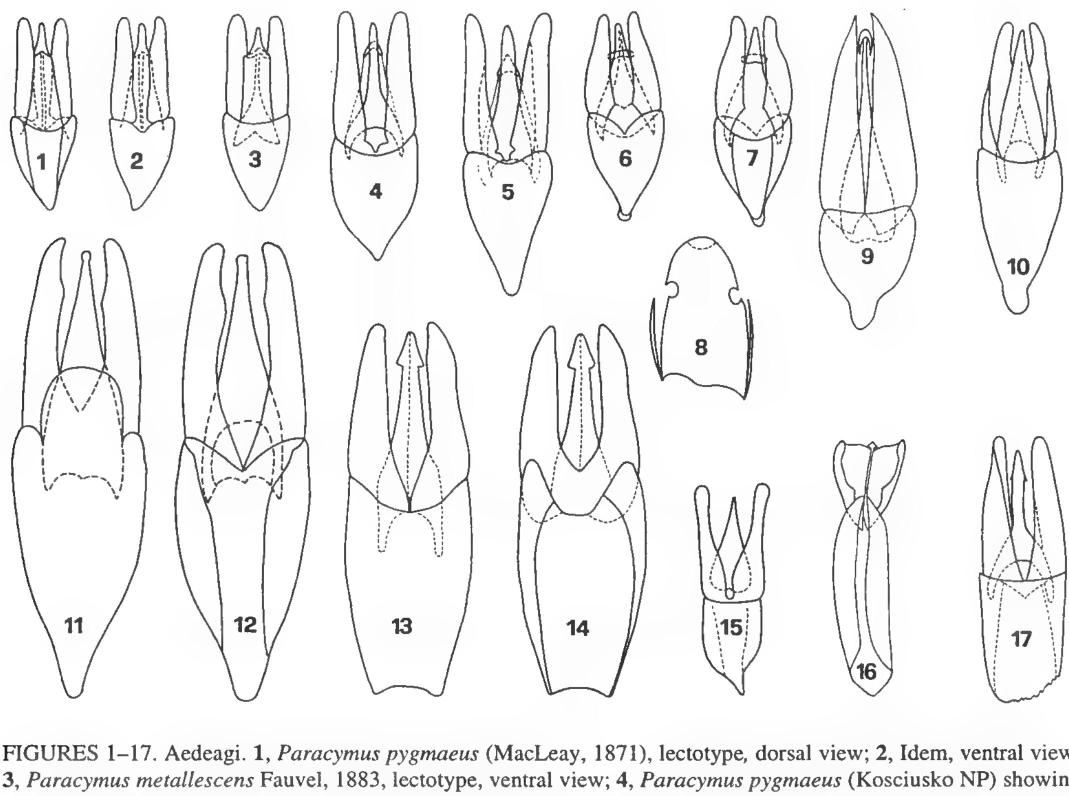
Synonyms

(1) *Hydrobius nitidiusculus* Broun, 1880. *Lectotype* female: **New Zealand**, Tairua, Broun 1880, NHML. A single pin bears the following cards and labels: 1. Insect; 2. 144; 3. Type (Circular label red-bordered); 4. Tairua; 5. New Zealand, Broun Coll., Brit. Mus. 1922-182; 6. *Paracymus nitidiusculus*; 7. female Lectotypus, *Hydrobius nitidiusculus* Broun, E. Gentili 1992 (red label). I did not see other types, but Broun certainly described the species based on more specimens, as in the description he states: 'I obtained the specimens now before me at Tairua and Whangarei Heads'. Blackburn (1888) wrote: 'Appears to be common in South Australia... I have taken it in Western Victoria also'. But in 1894 he wrote: '*Paracymus (Cyclonotum) pygmaeus*, Macl. I have recently received examples (compared with the type) of this insect from Mr. Lea. They seem certainly identical with *Paracymus (Hydrobius) nitidiusculus*, Brown. Macleay's is the older name'. After examination of the type, I agree with Blackburn.

(2) *Paracymus metallescens* Fauvel, 1883. *Lectotype* male (2.2 x 1.2 mm): **New Caledonia**, Tonghoué, Savès, ISNB. A single pin bears the following cards and labels: 1. Insect and its abdomen; 2. Aedeagus in DMHF; 3. Coll.

R.I.Sc.N.B., Nouvelle Calédonie, Tonghoué 9me, Rec. Savès, ex Coll. Fauvel (pink card); 4. Coll. et det. A. Fauvel, *Paracymus metallescens* Fvl., R.I.Sc.N.B. 17.479; 5. Syntype; 6. Lectotypus male, *Paracymus metallescens* Fauv., E. Gentili 1991. Three *paralectotypes* are also present in the ISNB, from the following localities: 1) Marais de l'anse Vata, juilliet 8me, Nouméa, Rec. Savès; 2) Kanala, Rec. Coste; 3) Koné, Rec. Atkinson. Fauvel (1883) wrote: 'Aussi en Australie'; and d'Orchymont 1926 stated: '*Paracymus metallescens* Fauvel, 1883 from New Caledonia is perhaps the same as *P. pygmaeus* W. S. MacLeay, 1871, from Australia, but no material from the original country could be seen'. Comparison with the Australian insects, including the aedeagus (Fig. 3), leads me to synonymise the two taxa.

(3) *Paracymus desolatus* Wooldridge, 1976. *Holotype* male (2.1 x 1.2 mm): **Western Australia**, Winjana Gorge, Ross & Cavagnaro 17.10.1962, CASF. A single pin bears the following cards and labels: 1. Insect with semiextracted aedeagus; 2. W. Australia: Winjana Gorge 100 m X.17.62; 3. Collectors E. S. Ross D. Cavagnaro; 4. male; 5. HOLOTYPE *Paracymus desolatus* Wooldridge (red label); 6. California Academy of Sciences Type No. 12007. *Paratypes*: the description quotes 143 males 149 females (including the allotype) from Northern Territory, Queensland, Western Australia, housed in CASF, NHML, SAMA, USNM. I here synonymise *P. desolatus* with *P. pygmaeus* after a long effort to isolate the true characteristics of *desolatus*. These might be: 1) pronotal punctation fine and widely separate, elytral punctation closer and more impressed; in *pygmaeus* pronotal and elytral



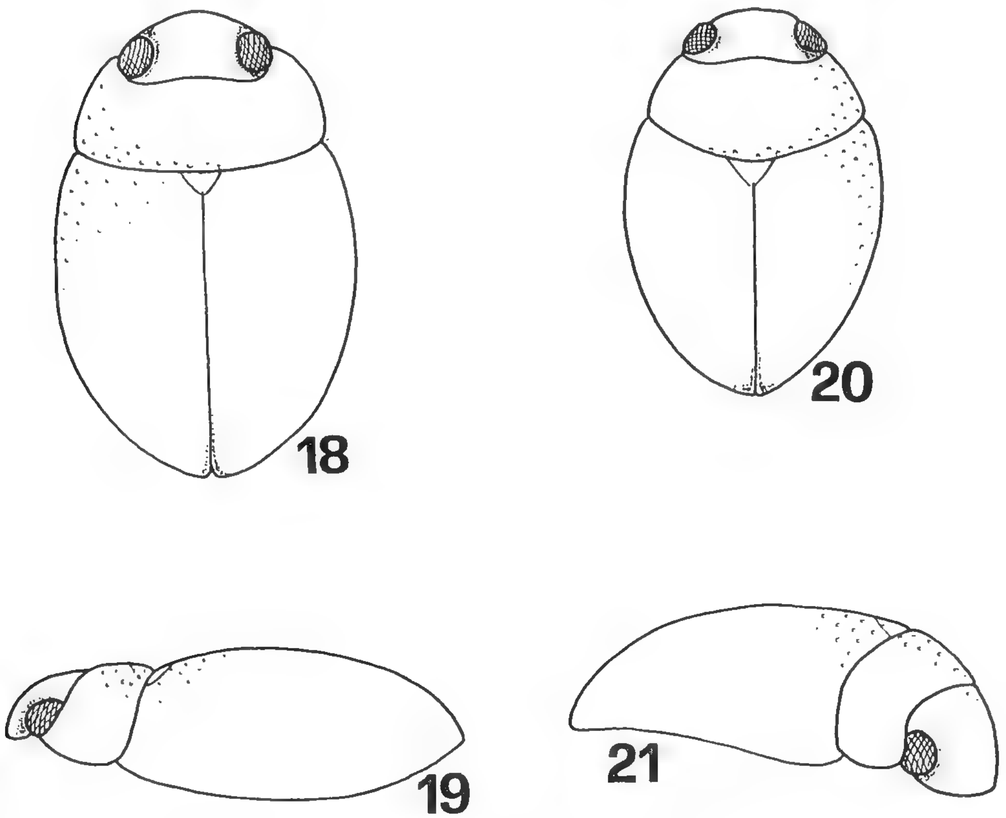
FIGURES 1–17. Aedeagi. **1**, *Paracymus pygmaeus* (MacLeay, 1871), lectotype, dorsal view; **2**, Idem, ventral view; **3**, *Paracymus metallescens* Fauvel, 1883, lectotype, ventral view; **4**, *Paracymus pygmaeus* (Kosciusko NP) showing the preapical collar and the connected membrane; **5**, *Paracymus pygmaeus* (Warburton): as in Fig. 4; **6**, *Paracymus spenceri* Blackburn, 1896, lectotype, ventral view; **7**, Idem, dorsal view; **8**, Idem, spiculum gastrale; **9**, *Paracymus cariceti* n. sp., holotype, ventral view; **10**, *Paracymus australiae* n. sp., holotype, ventral view; **11**, *Paracymus gigas* Gentili, 1996, holotype, ventral view; **12**, Idem, dorsal view; **13**, *Paracymus weiri* n. sp., holotype, ventral view; **14**, Idem, dorsal view; **15**; *Paracymus wattsi* n. sp., holotype, ventral view; **16**, *Paracymus opacus* n. sp., holotype, dorsal view; **17**, *Paracymus ovum* n. sp., holotype, ventral view.

punctation nearly equal. This character is conspicuous at 100 x but in a great number of sympatric specimens presents a high variability, from insects nearly impunctate to coarsely punctate on the whole dorsal surface; 2) the last segment of male protarsi less widened and hooked than in *pygmaeus*. I examined the holotype but was not able to distinguish the pattern of its protarsi from that of *pygmaeus*; 3) the mesofemora pubescent only on basal triangle, covering only 1/3 of anterior edge; in *pygmaeus* more pubescent, covering nearly 1/2 of anterior edge. In many cases this distinction is in my opinion impossible to see; 4) penis rapidly narrowing and becoming parallel-sided for about one-third its length; narrowly triangular in *pygmaeus*. Really the penis is narrowly triangular, due to a membranous expansion, from the base to a preapical collar in both forms. Sometimes the membranous expansion is scarcely visible or contracted, possibly due to effects of preservation.

(4) *Anacaena tepida* Winterbourn, 1970 is treated as a synonym of *P. pygmaeus* by R. Ordish in the above mentioned manuscript. But no author records it from Australia. Therefore I think it is not necessary to treat this species here.

Description

Length 1.6–3.0 mm; width 0.9–1.6 mm. Elongate oval, slightly convex (Figs 18, 19). Head black, evenly punctured, surface shining between punctures, occipital region alutaceous; transverse sutures distinct, coronal suture obsolete. Pronotum dark, a little paler at sides, black to reddish-brown, with olive-green reflections in some specimens; punctation finer than on head, obvious at sides, faint or absent on disc. Elytra uniform black to reddish-brown, with green reflections in some specimens, shining between punctures, punctures shallow like those of pronotum or shallower, but evenly distributed, with sparse setae laterally; parasutural furrow



FIGURES 18–21. **18**, Outline of *Paracymus pygmaeus* (MacLeay, 1871); **19**, Profile of *Paracymus pygmaeus*; **20**, Outline of *Paracymus wattsi* n. sp.; **21**, Profile of *Paracymus opacus* n. sp.

extended from apex nearly to anterior third of elytra. Under side dark; prosternum broadly keeled in middle and with a projection on anterior border; mesosternum with transverse ridge, a median keel anterior and posterior to it extending to both borders. First visible (third) abdominal ventrite with a median keel throughout its length. Palps pale yellow except for darkened apices; antennae pale yellow, eight-segmented. Profemur ventrally pubescent on proximal third; male protarsus with last segment shorter and broader than in female with two short, ventral, blunt spines; tarsal segments 1–4 (male protarsus) with a single ventral spine; protarsal claws of male less evenly curved than in female but equal in length. Ventral pubescence of mesofemur confined to proximal half or third and not reaching posterior border. Metafemur glabrous with weak longitudinal scratch-like impressions. Aedeagus (Figs 1–5) with tegmen pointed at base, parameres blunt at apex and scarcely longer than tegmen. Penis blunt at apex, with a collar at beginning of the apical third; from collar a membranous expansion reaches base of parameres describing a triangle; sometimes this expansion is scarcely conspicuous, possibly due to the methods of preservation (e.g. ethyl alcohol). Gonopore subapical and ventral.

Discussion

This is the most widespread *Paracymus* in Australia. Some of its characters, such as the dorsal punctation and the extension of the hairy surface on the mesofemora, show great variability. It is easy to separate from other species by the shape of its aedeagus: tegmen pointed at base (difference from *weiri* and *ovum*), scarcely shorter than parameres (difference from *opacus*, *gigas*, *weiri*, *australiae*, *cariceti*); penis simply pointed (difference from *cariceti*, *opacus*, *gigas*), with a preapical collar (as in *spenceri*, but the collar of *spenceri* lacks the membranous expansion). Other distinctive characters are the last protarsal segment of males, which is broader than in any other Australian *Paracymus*, and the scarce pubescence of the profemora.

Material examined (Fig. 22)

Australian Capital Territory: Black Mt., I. F. B. Common 12.11.1964 (1), 16.11.64 (4), 22–26.12.64 (1), 6.1.65 (1), 14.11.65 (1), 14.12.65 (6), 20.12.65 (6), 29.12.65 (9), 6.1.66 (2), 10.1.66 (2), 11.1.66 (2), 18.1.66 (1), 20.1.66 (1), 17.3.66 (2), 21.3.66 (2), 22.3.66 (1), light trap, ANIC; Black Mt., M. S. Upton 15.10.1965 (7), 8.12.65 (1), 15.12.65 (3), 16.12.65 (1), 22.12.66 (3), 24.1.67 (6), 16.10.67 (2), 30.11.67 (1), 12.12.67 (1), 10.1.68 (2),14.1.68 (1), 17.1.68 (2), 29.1.68 (1), 1.2.68 (2), 2.2.68 (1), 13.2.68 (2), 28.2.68 (1), 4.3.68 (1), 25.3.68 (2), 26.3.68 (5), 27.3.68 (2), 28.3.68 (3), 29.3.68 (3), 12–16.4.68 (1), 22.4.68 (1), light trap, ANIC; Black Mt., Z. Liepa 20.5.1966, ex rotting wood in creek (1); Black Mt., E. B. Britton 25.11.1964 (1) at light, ANIC; Black Mtn Reserve, S. Misko 4.12.1970 (2) light trap, ANIC; Black Mt. 600 m, 35°16'S 149°06'E, Weir Dressler & Lawrence 12.1986 (1) flight intercept window/trough trap, ANIC; Black Mt., Bywater & Clayton 23.1.1967 (1) from nest of Buff-tailed Thornbill, ANIC; Canberra, H. & A. Howden 2–3.XII.1986 (1) black light, ANIC; Cotter River, E. J. Pook 20.12.1965 (5) ANIC; Lake Burley Griffin, Z. Liepa 19.11.1965 (1) ANIC; Narrabundah Orchard, 21.11.1966 (1) ANIC; Paddy's River 1 mi S of Cotter Dam, S. Misko 17.4.1969 (2) ANIC; Piccadilly Circus 1240 m, 35°22'S 148°48'E, Lawrence Weir & Johnson 5.1984, 9.84, 12.84 (6) flight intercept window/trough trap ANIC; Piccadilly Circus, C. Reid 10.12.1984 (1) powerline clearing, ANIC; Piccadilly Circus 6 km NE, Wombat Ck, 35°19'S 148°47'E, 750 m, Weir Lawrence & Johnson 8. 1985 (1) flight intercept window/trough trap, ANIC; Snowy Flat Ck, Mt Gingera 0.5 km NE, 35°35'S 148°47'E, A. A. Calder 28.6.1988, ANIC. **New South Wales**: Albury, E. F. Riek 26.1.1963 (2) ANIC; Araluen, Apple Tree Ck, W. & S. Allen 6.12.1975 (1) ANIC; Berry, C. Watts 1.1967 (2) SAMA; Blue Mountains, Foulcon Bridge, 500 m, G. Wewalka 15.1.1993 (8) NMW, MSNV; Blue Mts, H .J. Cox (2) ANIC; Braidwood 15 km NW, Shoalhaven R., C. Reid 19.12.1984 (1) on Acacia spp., ANIC; Broken Head Nat. Reserve, Byron Bay 8 km S, Common & Edwards 23.11.1976 (2) ANIC; Canberra Coast Rd, Manar Ck, Britton & Misko 18.5.1967 (2) ANIC; Canberra Coast Rd, Cabbage Tree Ck, 7.7.1965 (1) ANIC; Casino 4 mi W, E. B. Britton at light (1) ANIC; Chichester St. Forest, Allyn R. Park, J. T. Doyen 8.XI.1982 (2), T. Weir 10–11.1981 ANIC; Chiswick nr Armidale, B. Clydesdale 12.1965 (5), 2.66 (2), 6.12.67 (1) ANIC; Clarence R., Brisbane, Coates, Griffith (6) SAMA; Cooma, Duboulay (3) ANIC; Coonabarabran 9 km W, 533 m, 31°17S 149°11'E, Common & Edwards 2.12.1974 (1) ANIC Coonabarabran 9 km NNE, Newe 11 Hwy, E. Britton 24.10.1980 Pilliga scrub (2) ANIC; Coonabarabran 14 km W, nr Timor Rock, J. Doyen 4.11.1982 (3) ANIC; Culcairn, E. W. Ferguson (4) ANIC; Darling R., Bourke 20 mi

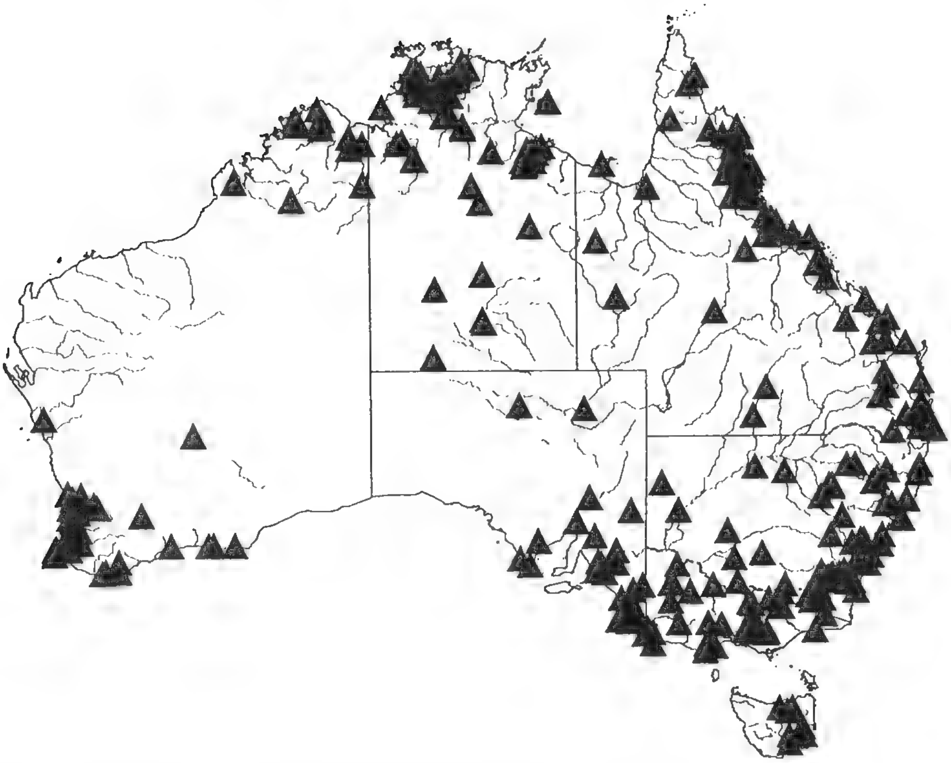


FIGURE 22. Distribution of the studied specimens of *Paracymus pygmaeus* (MacLeay, 1871).

SSW, on bank, G. F. Gross 26.12.1973 at light (1) SAMA; Delagate 14 km W, C. Watts 4.11.1997 (2) SAMA; Deniliquin, V. R. Squires 10.2.1966 light trap (1) ANIC; Dungong 35 km N, Chichester State Forest, Telegherry Forest Park, 300 m, Pollock & Reichert 18.12.1990 UV light along river (14) NMW, MSNV; Fowlers Gap Res. Stn, 31°05'S 141°42'E, Cardale & Naumann 29.11–2.12.1981 (18) at light, ANIC; Gilgandra, C. Watts 19.11.1992 (5) SAMA; Griffith, 34°17'S 146°03'E, R. Kohout 10.5.1972 (2) ANIC; Hay 23 mi. E, Britton & Misko 23.10.1967 at light (10) ANIC; Hay 8 km W, 34°30'S 144°51'E, Britton, Misko & Pullen 14.12.1970 (10) river bank, at light, ANIC; Hay 37 km E, E. G. Matthews 10.3.1971 (5) SAMA; Jenolan Caves, vicinity, J. C. Wiburd (4) SAMA; Jindabyne 13 km NE, Kara Ck 940 m, T. A. Weir 16.3.1979 (8) ANIC, MSNV; Jindabyne 12 km NNE, The Lake Ck 1160 m, T. A. Weir 16.3.1979 (11+10 not prepared) ANIC, MSNV; Jindabyne 6 km NW, Thredbo R. 500 m, T. A. Weir 15.3.1969 (1) ANIC; Jindabyne 10 km W, Wollindibby Ck 1060 m, T. A. Weir 15.3.1969 (2) ANIC; Khancoban, below Khancoban Dam 300 m, 36°13'S 148°06'E, dry sclerophyll forest, Newton & Thayer 13.2.1987 UV blacklight along river (43) FMNH; Kiandra, Alpine Ck, E. Britton 27.1.1966 (2) ANIC; Kosciusko NP, Diggers Ck 1510 m, T. A. Weir 14.3.1969 (2) ANIC; Kosciusko NP, Betts Ck 1740 m, 36°25'S 148°22'E, alpine meadow, Newton & Thayer 14.2.1987 ex *Sphagnum* etc. at stream edge and in bog (2) FMNH; Kosciusko NP, Leather Barrel Ck 980 m, 36°32'S 148°12'E, wet sclerophyll forest, Newton & Thayer 19.12.1986 flood debris ex large log jam, large forest stream (2) FMNH; Kosciusko NP, Sawpit Ck 1200 m, T. A. Weir 14.3.1969 (7) ANIC, MSNV; Kyogle 345 m, Newton & Thayer 2.3.1980 blacklight (1) USNM; Lake Bathurst, C. Reid 17.12.1984, shore mud & on grassland (1) ANIC; Macksville, Wachtel 12.1990 (1*f*) SAMA; Merindee Lakes Pk, Trust Caravan, G.P.Gross 26.12.1973 at light (6) SAMA; Moonbi Lookout 760 m, 30°58'S 151°06'E, Common & Edwards 11.12.1974 (1) ANIC; Moruya 8 km SE, Congo 35°58'S 150°09'E, M. S. Upton 8 & 14.2.1981 (2) ANIC; Mossgiel 11 km N, Willandra Bridge

33°16'S 144°34'E, dry swamp, Britton, Misko & Pullen 21.12.1970 at light (21) ANIC; Mt Kaputar, 2000 ft, C. W. Frazier 4.9.1964, at light (2) ANIC; Mt Keira, 1000 ft, Britton & Misko 7.3.1967 at light (1) ANIC; Mudgee 4 mi SW, 32°36'S 149°35'E, Britton & Misko 18.11.1968 (1) ANIC; Namoi R., Narrabri 30°19'S 149°47'E, J. A. L. Watson 10.3.1969 at light (1) ANIC; Nelson Bay 6 mi ESE, Britton & Misko 21.11.1967 at light (6) ANIC; Queanbeyan 2.7 km NE, 670 m, I. F. B. Common 11.11.1976 (1) ANIC; Sydney 100 m, H. P. Chandler 7.3.1943 (2) FMNH; Tamworth, Lea (2) SAMA; Uralla 6 km N, CSIRO Research Stn 'Chiswick', A. G. Furnival 10.1.1972 (10), 20.11.72 (2), 30.11.73 (4) ANIC; Valery, A. P. M. *Eucalyptus* plantation, Mc Mullens Block, R. McInnes 10.1.1967 (1) light trap, ANIC; Wahroonga, H. J. Carter (4) ANIC; Warrumbungle NP, Siding Spring Mtn, C. Reid 23.XI.1985, *Eucalyptus* forest at light (8) ANIC; Wee Jasper, E. F. Riek 20.4.1961 (4) ANIC; Wentworth Fs, 5.1.1895 (1) SAMA; Wingello 3 km SW, S. Misko 20.2.1974 (4) ex pool, ANIC; Wingham Scrub, 31°52'S 152°22'E, rainforest edge, Britton & Misko 3.1.1970 (3) at light, ANIC; Woy Woy, Pearl Beach, C. Reid 1.12.1984 at light (1) ANIC. **Northern Territory**: Adelaide R., at Daly R. Road Crossing, 13°29'S 131°06'E, E. B. Britton 9.11.1972 (12) ANIC; Adelaide R., 10 km on Daly R. Road, E. F. Riek 25.10.1972 (1) ANIC; Adelaide R., 13°15'S 131°06'E, M.S.Upton 17.10.1972 (14) ANIC, MSNV; Adelaide R. 27 km N, Coomalie Ck, Gross & Forrest 28.9.1977 at light (16) SAMA; Alice Springs 6 mi SE, Emily Gap, Britton, Upton & Mc Innes 17.2.1966 (1) ANIC; Alice Springs 9 km N, Todd R., 23°38'S 133°53'E, M. S. Upton 10.10.1978 (1) ANIC; Alroy Downs HS 15 km SW, 19°24'S 135°58'E, Key & Balderson 10.4.1976 (7) ANIC; Barrow Ck 2 mi S, Britton, Upton & McInnes 13.2.1966 (4) ANIC; Boko Hill 1 km N, SW of Borroloola, 16°26'S 136°01'E, Key & Balderson 14.4.1976 (2) ANIC; Borroloola 2 km SSE, McArthur R., 16°05'S 134°19'E, J. E. Feehan 19–20.4.1976 (1) ANIC; Borroloola 4.5 km W, T. Reardon 8.1982 (1) SAMA; Borroloola 11 km SW, Goose Lagoon, 16°10'S 136°15'E, J. E. Feehan 17.4.1976 at light (9), M. S. Upton 31.10.1975 (1) ANIC; Borroloola 12 km NNE, 15°58'S 136°21'E, M. S. Upton 1.11.1975 (3) ANIC; Borroloola 22 km WSW, 16°08'S 136°06'E, J. E. Feehan 16.4.1976 at light (30), M. S. Upton 2.11.1975 (11) ANIC; Borroloola 30 km NE, Batten Point, 15°54'S 136°32'E, J. E. Feehan 18.4.1976 at light (9) ANIC; Borroloola 31 km WSW, Batten Ck, 16°10'S 136°03'E, J. E. Feehan 15.4.1976 at light (7) ANIC; Borroloola 33 km SW, Caranbirini W.H., 16°16'S 136°05'E, J. E. Feehan 21.4.1976 at light (10), M. S. Upton 3.11.1975 (10) ANIC; Borroloola 45 km SW, Surprise Ck, 16°25'S 136°05'E, M.S.Upton 5.11.1975 (1) ANIC; Borroloola 46 km SSW, 16°28'S 136°09'E, J. E. Feehan 23.4.1976 (4), M. S. Upton 28.10.1975 (1) ANIC; Borroloola 48 km SW, McArthur R., 16°27'S 136°05'E, J. E. Feehan 13.4.1976 at light (4), M. S. Upton 29.10.1975 (1) ANIC; Borroloola 54 km S, Cattle Ck, 16°32'S 136°10'E, M. S. Upton 27.10.1975 (1) ANIC; Borroloola 80 km SW, McArthur R., 16°39'S 135°51'E, M. S. Upton 13.5.1973 (10) ANIC, MSNV; Burrell's Ck, Stuart H'way, D. H. Colless 25.11.1972 at light (1) ANIC; Cahills Crossing, E Alligator River, 12°26'S 132°58'E, E. B. Britton 31.10.1972, 3.12.1972 at light (5), E. G. Matthews 29.5.1973 at light (10) ANIC, SAMA; Cahills Crossing 1 km N, E Alligator R., 12°23'S 132°57'E, Upton & Feehan 7.6.1973 (7), E. Britton 31.10.1972 at light (2) ANIC; Cahills Crossing 5 km NNW, E Alligator R., 12°23'S 132°57'E, E. B. Britton 5.11.1972 (1), E. G. Matthews 28.5.1973 (10), Upton & Feehan 8.6.1973 (4), A. H. Watson 8.6.1973 (1) ANIC, SAMA; Cahills Crossing 7 km NW, E Alligator R., 12°23'S 132°56'E, E. B. Britton 4.11.1972 at light (10), E. G. Matthews 27.5.1973 (10) ANIC, SAMA; Cape Crawford 8 km ESE, Bessie Springs, 16°40'S 135°51'E, J. E. Feehan 12.4.1976 at light (13) ANIC; M. S. Upton 26.10.1975 (11), J. E. Feehan 12.4.1976 at light (3) ANIC; Cape Crawford 14 km NW, 16°34'S 135°41'E, M. S. Upton 6.11.1975 (15) ANIC; Cape Crawford 14 km S, Mc Arthur R., 16°47'S 135°45'E, M. S. Upton 25.10.1975 (9), J. E. Feehan 11.4.1976 (16) ANIC; Colyer Lagoon, October Ck, Gross & Forrest 26–27.9.1977 at light (3) SAMA; Curtin Springs HS., Thurmer & Lacis 17.8.1978 (1) SAMA; Daly R., J. C. Lesoeuf 12.7.1971 (5) ANIC; Daly River 10 mi E, B. K. Head 28.6.1972 at light (41) SAMA; Daly R. Mission, J. Hutchinson 6.6.1974, 8.10.1974 at light (2) ANIC; Darwin, F. J. Gay 24.4.1966 (2) ANIC; Darwin, B. Malkin 25.3.1945 (1) FMNH; nr Darwin, Coastal Plains Rsrch Station CSIRO, E. C. B. Langfield 6.6.1966 at light (17), 30.5.1966 at light (8) ANIC, MSNV; Darwin 24 km S, Howard Springs, 12°28'S 131°03'E, E. B. Britton 10.11.1972 rainforest, at light (3), J. A. L. Watson 27.1.1968 at light (1) ANIC; Darwin 30 km SSE, Berry Springs, 12°41'S 130°58'E, E. B. Britton 11.11.1972 at light (2) ANIC; Darwin 50 km S, Coomalie Ck, G. F. Gross 28.9.1977 (1) SAMA; Darwin 52 km S, Livingstone Field, Stuart Highway, 12°44'S 132°05'E, E. B. Britton 9.11.1972 at light (16) ANIC; East Point, nr Darwin, 12°28'S 130°50'E, E. B. Britton 12.11.1972 in flowers of *Hybiscus tiliaceus* (1) ANIC; Elliott 15 km SW, L. Woods, Gross & Forrest 5.10.1977 at light (25) SAMA; Groote Eylandt, N. B. Tindale, in moss and lichens (1) SAMA; Jabiru, C. Watts 22.3.1998 (6) SAMA, MSNV; Kakadu NP, Upper S Alligator R., 13°35'S 132°36'E, P. S. Cranston 4–5.6.1988 light trap (8) ANIC; Katherine, L. P. Kelsey 16.8.1973 at light (1), E. G. Matthews 6–10.2.1968 (1) ANIC; Katherine Gorge, M. J. Muller 26.10.1975 light trap (2) ANIC; Katherine 3 km SSW, 14°30'S 132°15'E, T. Weir 12.11.1979 (4) ANIC; Katherine 25 km NE, Katherine R., Gross & Forrest 3–4.10.1977 at light (24) SAMA; Koongarra 12°52'S 132°50'E, M. S. Upton 6–10.3.1973 (4) ANIC; Mataranka 5 km E, Roper R., Gross & Forrest 27.9.1977 at light (8) SAMA; Mataranka 19 km SSE, Elsey Ck, 15°05'S 133°07'E, M. S. Upton 14.5.1973 (9) ANIC; Mt Borradaile 19 km E, Cooper Ck 12°06'S 133°04'E, E. B. Britton 2.11.1972 (4), E. G. Matthews 31.5.1973 at light (25), M .S. Upton 9.11.1972 (1), 5.6.1973 (8) ANIC, SAMA; Mt Cahill 6 km E, 12°52'S 132°46'E, Nourlangie Ck, M. S. Upton 18.11.1972 (2) ANIC; Mt Cahill 8 km N, Nourlangie Ck, 12°48'S 132°42'E, E. B. Britton 26.10.1972 (14), id., D. H. Colless (1), M. S. Upton 19.11.1972 (3), Upton & Feehan 16.6.73 (23), E. G. Matthews 21.5.73 (6) at light ANIC, SAMA, MSNV; Mt Cahill 8 km E, Nourlangie Ck, 12°52'S 132°47'E, E. B. Britton 27.10.1972 (58), id., mud at edge of waterhole (7), E. G. Matthews 22.5.1973 at light (9) ANIC, SAMA, MSNV; Mt Cahill 10 km E, 12°51'S 132°47'E, E. G. Matthews 21.5.1973 (2) ANIC; Mt Cahill 12 km NNW, 12°46'S 132°39'E, E. B. Britton 25.10.1972 at light (1), Matthews & Upton 20.5.1973 (20), Upton & Feehan 15.6.1973 (3) ANIC, SAMA; Mt Cahill 15 km E, Koongarra, 12°52'S 132°50'E, M. S. Upton 15.11.1972 (11), Upton & Feehan 12.6.1973 (9) ANIC; Mt Cahill 15 km E by N, 12°50'N 132°51'E, E. B. Britton 29.10.1972 at light (4), D. Colless 30.10.1972 by sweeping (8) ANIC; Mt Cahill 16 km E by N, 12°50'S 132°51'E, Upton & Feehan 13.6.1973 (14) ANIC, SAMA; Mt Cahill 19 km NE, Baroalba Ck Springs, 12°47'S 132°51'E, E. B. Britton 28.10.1972 (43), M. S. Upton 16.11.1972 (8) ANIC; Mt Cahill 19 km WSW, Jim Jim Ck, 12°57'S 132°33'E, E. B. Britton 24.10.1972 at light (8), Upton & Feehan 17.6.1973 (6) ANIC, SAMA; Mt Cahill 30 km WSW, 12°58'S 132°26'E, E. G. Matthews 19.5.1973 (1) ANIC; Mt Cahill 46 km WSW, S Alligator River, 13°03'S 132°19'E, Matthews & Upton 20.5.1973 (7) SAMA, ANIC; Mudginbarry HS. 2 km N, Magela Ck, 12°35'S 132°52'E, M. S. Upton 14.11.1972 (9) ANIC; Mudginbarry HS. 9 km SSE, Magela Ck, 12°40'S 132°54'E, E. B. Britton 6.11.1972 at light (20) ANIC; Mudginbarry HS. 9 km N, 12°31'S 132°54'E, Upton & Feehan, E. G. Matthews 26.5.1973 (12) ANIC, Upton & Feehan 10.6.1973 (9) ANIC, SAMA, E. B. Britton 30.10.1972 (16) ANIC; Nabarlek Dam, 15 km S of Nimbuwah Rock, 12°20'S 133°19'E, E. G. Matthews 2.6.1973 at light (10) ANIC, SAMA; Nimbuwah Rock 11 km S, Cooper Ck, 12°17'S 133°20'E, E. B. Britton 1.12.1972 at light (12), Feehan & Upton 3.6.1973 (3) ANIC; Oenpelli 6 km SW, 12°22'S 133°01'E, E. G. Matthews 30.5.1973 at light (2), Upton & Feehan 6.6.1973 (5) ANIC, SAMA; Oenpelli 18 km E, 12°17'S 133°13'E, Matthews & Upton 1.6.1973 (6) ANIC; Pine Ck, C. Watts 5.5.1963 (2) SAMA; Port Keats, 14°06'S 129°33'E, M. Mendum 19.8.1968 (1) ANIC; Renner Springs 4.8 km S, N. McFarland 8.3.1966 UV light (11) SAMA; Timber Ck 4 mi W, N. McFarland 14.4.1966 UV light (67) SAMA; Tindal, 14°31'S 132°22'E, W. J. M. Vestjens 1–20.12.1967 light trap (50) ANIC, MSNV; Victoria River Downs 6.4 km SSW, L. P. Kelsey 14–17.7.1973 (4) ANIC; Victoria River Downs 4 mi. WSW, Irrigation Farm, L. P. Kelsey 13.9.1973 (2) ANIC; Victoria River Downs 8 km WSW, L. P. Kelsey 14.8.1973 at light (10) ANIC; Yuendumu, C. Watts 3.1965 (3) SAMA; Wildman River Lagoon, 12°58'S 132°00'E, E. B. Britton 24.10.1972 (6) ANIC; Woolwonga Fauna Res., Dreaming Water, E. F. Riek 20.10.1972 (2) ANIC, MSNV. **Queensland**: Annan Falls 1 km W, 15°31'S 145°14'E, E. B. Britton 26.5.1976 (7) ANIC; Archers Ck, Mt Garnet Rd., J. G. Brooks 28.12.1964 (2) ANIC; Archers Ck 2220', J. G. Brooks 18.4.1974 at light (9) SAMA; Barkley Hwy 7 mi N, on Burketown Rd., J. A. Forrest 23.9.1977 burnt out area, some regrowth, at light (1) SAMA; Boulia 42 km NNW, 22°35'S 139°43'E, M. S. Upton 11.5.1973 (1) ANIC; Bowen, A. Simson (1) SAMA; Brisbane (4) SAMA; Brisbane 50 km S, Canungra, Pollock & Reichert 11.1.1991, black light (105) NMW, MSNV; Cape York Pen., Old Strathgordon, H'stead W of Musgrave, Walford & Huggins 24.11.1983 (9) ANIC; Cardstone, J. G. Brooks 14.11.1966 (3), K. Hyde 17–23.2.1966 (13)

ANIC; Cardwell Range, J. G. Brooks 30.9.1967 (8) ANIC; Charleville S, M. S. Upton 9.5.1973 (1) ANIC; Cairns Distr., A. M. Lea, at light (6) SAMA; Chillagoe Ck, campsite, Ellis & Hawkins 8.8.1967 (1) ANIC; Cooktown, Airport Rd., roadside swamp, 15°28'S 145°11'E, E. B. Britton 24.5.1976 (9) ANIC; Cooktown 3 km S, Keatings Gap, 15°30'S 145°15'E, Common & Edwards 16.5.1977 (6) ANIC; Cooktown 21 km W, 15°25'S 145°03'E, Common & Edwards 17.5.1977 (5) ANIC; Cooktown 25 mi N, Mc Ivor R., S. R. Curtis 6.5.1970 (37) ANIC; Cooktown 75 km, Cooktown Rd., Boggy Ck, E. B. Britton 26.4.1976 (8) ANIC; Cunnamulla, A. Hardcastle (2) SAMA; Dalby, F. H. Hobler, Griffith Coll. (1) SAMA; Dalrymple 300 m, 30 km N Charters Towers (2) NMW; Eidsvold N, Burnett R., 24°46'S 152°25'E, Holloway & Misko 10.1.1970 at light (2) ANIC; Forty Mile Scrub N. P., Mt Garnet 52 km SW, 18°05'S 144°52'E, Weir & Calder 21.7.1986 (24), 55 km S, 18°06'S 144°50'E, J. Balderson 29–30.11.1981 (1) ANIC; Funnel Ck, 21°47'S 148°55'E, Britton & Misko 12.12.1968 at light (7) ANIC; Gladstone 23 km SE, Calliope R., 23°50'S 151°13'E, S. Misko 23.1.1970 (11) ANIC; Green Hills, J. G. Brooks 19.12.1967 (3) ANIC; Herberton 7 mi SW, 17°27'S 145°27'E, Britton & Misko 6.12.1968 at light (8) ANIC; Hope Vale Mission 7 km N, 15°14'S 145°07'E, T. Weir 4.10.1980 (1) ANIC; Ingham, K. L. Harley 24.2.1960 (2), 30.3.1960 (2) ANIC; Ingham 23 mi SSE, 18°58'S 146°16'E, Britton & Misko 9.12.1968 at light (69) ANIC; Iron Range, 12°42'S 143°18'E, J. G. & J. A. G. Brooks 15.5.1971 at light (1) ANIC; Julatten, Bushy Ck, 16°37'S 145°21'E, E. B. Britton 3.12.1968 from gravel at water's edge (12) ANIC; Kelly, St George R., Cooktown Rd, 16°29'S 144°47'E, E. B. Britton 22.5.1976 (1) ANIC; Kennedy Forest Rd, rainforest 18°13'S 145°47'E, Britton & Misko 8.12.1968 (1) ANIC; Kingaroy 24 mi SW, 26°44'S 151°31'E, Britton & Misko 21.11.1968 (1) ANIC; Kuranda, Barron Falls, J. G. Brooks 12.12.1964 (2) ANIC; Lake Barrine, 18–22.9.1965, E. Britton (2) ANIC; Laura, C. Watts 18.7.1982 (3), 2.8.1974 (1) SAMA; Laura 73 km NW, Hann R., 15°12'S 143°52'E, Weir & Calder 27.6.1986 (25) ANIC; Longreach 31 km NW, Darr R., 23°13'S 144°04'E, M. S. Upton 10.5.1973 (8), 22.10.1975 Darr R. (3) ANIC; L'tle Mulgrave R., J. G. Brooks 16.12.1967 (11) ANIC; MacDonald N.P., Mt Tamborine, J. & E. Doyen 26.11.1982 (1) ANIC; Mackay W, Finch Hatton Ck, 21°08'S 148°38'E, S. Misko 29.11.1968 (5) ANIC; Mackay 50 mi W, Broken River, Misko & Britton 29.11.1968 rainforest, at light (2), S. Misko 30.11.1968 (6) ANIC; Mareeba, K. & E. Carnaby 22.5.1976 (1) ANIC; Mareeba 24 km N, 16°47'S 145°22'E, J. Balderson 24–25.11.1981 (1) ANIC; Mary Ck, 16°33'S 145°12'E, Britton & Misko 4.12.1968 at light (108) ANIC; Mary Ck, 22 km N of Mt Molloy, J. G. Brooks 14.3.1970 at light (20) ANIC; Miriam Vale 21 mi S, 24°38'S 151°34'E, Britton & Misko 14.12.1968 (14) ANIC; Monto 22 km NW, Coominglah St. For., J. T. Doyen 23.12.1982 (4) ANIC; Mornington Island Mission, Aitken & Tindale 7–11.5.1963 at light (4) SAMA; Mourangee nr Edungalba, 50 mi SW of Rockampton, E. Adams 24.11.1968 at light (3), Britton & Misko 26.11.1968 at light (2) ANIC; Mt Baird 3.5 km SW, 15°10'S 145°07'E, A. Calder 3–5.5.1981 (7) ANIC; Mt Baldy nr Atherton, Forest Res. No. 194, 4000', rainforest, Britton & Misko 5.12.1968 (13) ANIC; Mt Carbine 35 km NNW, J. T. Doyen 13.12.1982 (2) ANIC; Mt Cook N. P., 15°29'S 145°16'E, A. Calder 10–12.5.1981 (1) ANIC; Mt Coolum, 26°35'S 153°05'E, Britton & Misko 15.12.1968 at light (25) ANIC; Mt Inkerman 2 mi SW, 19°45'S 147°30'E, Britton & Misko 11.12.1968 mud, lily ponds (4) ANIC; Mt Lewis, ca. 3000', rainforest, Britton & Misko at light tin working site, 3.12.1968 (2) ANIC; Mt Molloy 17.7 km N, Station Ck 427 m, J. G. Brooks 21.12.1970 (1) ANIC; Mt Tozer 3 km ENE, 12°44'S 143°14'E, Weir & Calder 28.6–4.7.1986 (23), J. C. Cardale (1) ANIC; Mt Tozer 11 km ENE, 12°43'S 143°18'E, Weir & Calder 11–16.7.1986 (5) ANIC; Mt Webb 3 km NE, 15°03'S 145°09'E, A. Calder 30.4–3.5.1981 (3) ANIC; Nettle Ck, J. G. Brooks 20.8.1969 (2) ANIC; Normanton, Tindale & Aitken 4.5.1963 at light (3) SAMA; Paluma 2 km W, Ewan Rd 800 m, 19°06'S 146°34'E, J. G. Brooks 22.2.1972 at light (1) ANIC; Paluma 9 km W, J. G. Brooks 4–13.12.1973 at light (1) ANIC; Pentland, J. C. Lesoeuf 18.7.1975 (1) ANIC; Pistol Gap, Byfield, 22°50'S 150°40'E, Britton, Holloway & Misko 10.1.1970, dry sclerophyll, at light (4) ANIC; Proserpine 8 mi NE, Brandy Ck, 20°20'5S 148°41'E, Britton & Misko 11.12.1968 at light (2) ANIC; Ravenshoe 17.7 km W, Archers Ck, J. G. Brooks 13.4.1974 (18) ANIC; Reedy St George R., Cooktown Rd, E. B. Britton 22.5.1976 (1) ANIC; Stanthorpe 9 mi. S, Conardoo, Fletcher 28°46'S 151°51'E, Britton & Misko 20.11.1968 (6) ANIC; Station Ck, J. G. Brooks 14.4.1970 (2) ANIC; Stuart R., Hale & Tindale 1–2.1927 (2) SAMA; Summit 4 km W, Cunninghams Gap N.P., J. Doyen 27–28.11.1982 (1) ANIC; Townsville, B. Malkin 1–2.1945 (2) FMNH; Townsville, P.

Ferrar 23–30.5.1968 light trap (1) ANIC; Townsville 10 m, G. Wewalka 17.1.1993 (2) NMW; Townsville 5 km N, at Town Common, 19°15'S 146°48'E, S. Misko 19.1.1970 at light (1) ANIC; Wenlock R., Xing Portland Roads Road, 13°06'S 142°56'E, Weir & Calder 17.7.1986 (1) ANIC; Woodstock 7 km S, Lansdown Station, 19°40'S 146°51'E, R. A. Barrett 16.1.1974 (4) ANIC. **South Australia**: Barossa, B. J. Burton (2) SAMA; Devon Downs, S. A. Museum Exped. (1) SAMA; Donovans 6.4 km NW, Ponds Cave, Aitken & Tindale 28.1.1965 (13) SAMA; Eyre Pen., McKeckives Spr., White Flat Rd, Bishop & Diener 14.12.1976 (8) SAMA; Eyre Pen., Strm nr Epsom Sp., White Flat Rd., Bishop & Diener 14.12.1976 (6) SAMA; Eyre Pen., Todd R., White Flat Rd., Bishop & Diener 14.12.1976 (9) SAMA; Eyre Pen., Woolshed Ck, Bishop & Diener 13.12.1976 (2) SAMA; Fairview Cons. Pk, J. A. Forrest 1.4.1982 at light (12) SAMA; Fairview Wildlife Res., 36°49'S 140°24'E, Matthews & Forrest 23.3.1981 at light (2) SAMA; Finness R., R. Malcolm 4.1976 (2) SAMA; Flinders Ranges, Arkaba Ck, E. G. Matthews 5.3.1973 (1) SAMA; Lake Fox edge, P. J. M. Greenslade 18.11.1978, ex litter samples (1) SAMA; Lake George, 37°20'S 140°10'E, Roffey & Mitchell 13.10.1972 (1) ANIC; Monarto Sth, P. McQuillan 19.1.1973 UV light (2) SAMA; Mosquito Ck SE mouth at Haks Lagoon, Thurmer & Gackle 23.4.1979 in water (1) SAMA; Mt Crawford Forrest, C. Watts 10.11.1996 (3) SAMA; Mt Gambier 27 km NE, nr Linwood Pk., swamp in Pine forest, J. A. Forrest 26.3.1982 (4) SAMA; Mt Gambier, Valley Lake, K. F. Walker 1.1.1975 (11) SAMA; Mt Remarkable NP, Mambray Ck, J. A. Forrest 7.5.1981, E. G. Matthews 17.1.1982 (7) SAMA; Murbko, R. Murray, G. F. Gross 20.2.1973 (2) SAMA; Murray R., R. J. Burton (3) SAMA; Mylor, Scout Jamboree 20.12.1973–6.1.74, el. light (1) SAMA; Nanam's Well 15 km SW, Scorpion Springs C.P., Museum Party 14.12.1983, at light (2) SAMA; New Kalamurina St., Warburton R., Matthews & Houston 9.3.1972 (1) SAMA; Olary 24 km WNW, 32°17'S 140°19'E, Britton, Misko & Pullen 20.12.1970 at light (3) ANIC; Oodnadatta, Blackburn (1) SAMA; Penola Cons. Pk, Penola 14 km W, J. A. Forrest 24.3.1982 (1) SAMA; Penola W nr Calectasia NP, Baker Range Drain, J. A. Forrest 24.3.1982 (12) SAMA, MSNV; Port Lincoln, Blackburn (5) SAMA; Robe 10 km S, C. Watts 1.1983 (2) SAMA; Rudall 2 km S, 33°41'S 136°16'E, Britton, Misko & Pullen 18–19.12.1970 (1) ANIC; Salt Creek 17 mi SE, Gross & Aitken 14.1.1962 at light (3) SAMA; Tintinara 15 mi E, Jimmy's Well, Aitken & Tindale 3.2.1965 (2) SAMA; Yorke Pen., 8 km WSW Carritin Hs., S end of Formby Lisy, N. McFarland 4.11.1965 (1) SAMA. **Tasmania**: Barrow Ck, Mt Barrow 6 km NW, 41°21S 147°22'E, E. & S. Britton 3.2.1973 (1) ANIC; Forest Reefs, Griffith Coll. (4) SAMA; Frankford, A. M. Lea (2) SAMA; George, C. E. Cole 3.11.1917 (2) SAMA; Hobart, base Mt Wellington, L. Hill 26.1.1979 ex moss & grass (1) ANIC; Kelso (1) SAMA; Kempton Water Tray, L. Hill 28.11.1985 (1) ANIC; Launceston, F. M. Littler (2) SAMA; Orford 4 km W, 42°34'S 147°50'E, J. C. Cardale 27.1.1983 at light (1) ANIC; Tooms R., 460 m, 42°13'S 147°46'E, L. Hill 19.4.1981 (4 *ff*) ANIC, MSNV. **Victoria**: Alexandra 25 km S, Cathedral Range Nat. Park, Blackwood flat Campground, 445 m, Pollock & Reichert 5.12.1990 black light (1*f*) NMW; Ballarat, W. W. Froggatt (1) ANIC; Baw Baw Alpine Res., Neulines Mill 1.2 km NW, 1145 m, 37°51'S 146°15'E, wet sclerophyll & *Nothofagus cunninghami*, Newton & Thayer 29.1.1987 berlese leaf and log litter forest floor (1*f*) FMC; Billabong, Yara Glen, A. Fletcher 20.4.1976 (1) SAMA; Birchip V., J. C. Goudie (1*f*) ANIC; Dartmooor 5 km NE, C. Watts 11.10.1997 (1) SAMA; Dimboola, Caravan Park, S. Misko 18.11.1973 light trap (5) ANIC; East Pomborneit, 24 km ESE Campdown, temporary pond, P. S. Lake 5.X.1978 (5) ANIC; Healesville, Goudie & Lea 11.? (1), C. Watts 12.1968 (5) SAMA, MSNV; Kawarren 3 km N, Otway Ranges, Gross & Aitken 15.1.1962 at light (14) SAMA; Kerang, R. Blackwood 4.1935 (1) ANIC; Lake Hattah (4) ANIC; Lake Hattah, G. W. Anderson 24–25.10.1967 (2), 28.11.1967 (4), 9–15.3.1969 (2), 9.12.1969 (4) light trap ANIC; Lake Learmonth, E. F. Riek 15.12.1966 (2*ff*) ANIC; Lerderderg R., 3.8 km WNW Blackwood, A. J. Boulton 27.6 & 25.11.1982 (3) ANIC; Lilydale, A. Fletcher 2.7.1976 (1) SAMA; Lorne, Cressy Ck, N. B. Tindale 21.1.1963 (5) SAMA; Mirrantwa 10 km NE, C. Watts 12.10.1997 (11) SAMA; Mt Buffalo, Blackburn (5) ANIC, SAMA; Mt Buffalo NP, 1310 m, alpine bog, *Sphagnum* moss, Newton & Thayer 18–19.1.1980 (1) FMNH; Noojee 6 km N, C. Watts 8.11.1997 (2) SAMA; Orbost 12 km SW, C. Watts 5.11.1997 (5) SAMA; Otway NP, Binn Rd. 450 m, Cape Horn 58 km N, 38°42'S 143°34'E, wet sclerophyll forest, Newton & Thayer 24.1.1987 (1) FMNH; Ovens R., Wangaratta, Newton & Thayer 9.1.1980 black light (1*f*) ANIC; Ovens R., Porepunkah, 300 m, 36°42'S 146°55'E, mixed dry sclerophyll and exotic trees, Newton & Thayer 12.2.1987 UV blacklight nr River (1*f*) FMNH; nr Porepunkah, A. Newton 18.1.1980 UV light (1) ANIC; Portland 30 km W, C. Watts 10.10.1997 (2) SAMA; Shepperton 13 km SE, S. Misko 22.11.1973 (2*ff*) ANIC; Tangil River E, C. Watts 8.11.1997 (8) SAMA; Violet Town 14 km NW, Rd to Shepperton, S. Misko 22.XI.1973 (5) ANIC; Yarra River, Healesville 4,5 km SW, 80 m, 37°41'S 145°29'E, dry sclerophyll forest, Newton & Thayer 6.2.1987 UV black light along river (195) FMNH; Warburton, A. Newton 13–17.1.1980 UV light (1*f*) ANIC; Warburton 12 km E, 215 m, *Eucalyptus* forest, leaf litter stream edge, Newton & Thayer 12–16.1.1980 (1) FMNH; Wyperfield Nat. Park, Frew's Plain 35°37'S 142°01'E, S. Misko 15–17.XI.1973 at light (14) ANIC, MSNV; Wyperfield Nat. Park, Lowan Treck 35°35'S 142°05'E, S. Misko 16.XI.1973 light trap (21) ANIC, MSNV; Wyperfield Nat. Park, Ranger's House, 35°37'S 142°01'E, Misko & Anderson 17.XI.1973 light trap (4) ANIC; Wyperfield NP, Common-Upton 5.11.1966 (1) ANIC. **Western Australia**: Albany, K. & E. Carnaby 15.12.1976 (5) ANIC; Albany 48 km N, Porongorup NP, J. Kethley 24.12.1976 soil litter und grasses (1) FMNH; Appleton, F. H. Uther Baker, 4.1.1966 (10) ANIC; Armadale 15 mi SSE, Pipehead Dam, M. S. Upton 26.1.1967 (7) ANIC; Armadale, D.E. 7.1961 (1) SAMA; Beverley, A. M. Lea 1870 (5) SAMA; Bunbury, K. & E. Carnaby 31.12.1971 at light (14) ANIC; Bunbury, Whitlock (7) ANIC; Capel, E. Britton 29.10.1965 (6) ANIC; Carson Escarpment, 14°49'S 126°49'E, Common & Upton 9–15.8.1975 (11) ANIC, MSNV; Collie 16 mi N, Common & Upton 7.4.1968 (1) ANIC; Coodanup nr Mandurah, T. E. Bellas 12.1979–1.1980 (1) ANIC; Darling Rgs., A. M. Lea (1) SAMA; Deepdene, Karridale, M. S. Upton 18.1.1967 (10) ANIC; Denmark, Walpole Rd, roadside pool, E. Britton 21.9.1965, 24.9.65 (2) ANIC; Denmark 14 mi E, Parry's Inlet turnoff, 35°01'S 117°09'E, E. Britton 9.11.1969 roadside pond (45) ANIC; Donnybrook, A. M. Lea 1870 (3) SAMA; Drysdale R., 15°02'S 126°55'E, Common & Upton 3–8.8.1975 (10) ANIC; Drysdale R., 14°39'S 126°57'E, Common & Upton 18–21.8.1975 (10) ANIC, MSNV; Dunsborough 20 m, J. B. Kethley 11.1976 at light (1) FMNH; Esperance 20 km E, 33°50'S 122°06'E, J. F. Lawrence 8.11.1977 at light (16) ANIC; Esperance 101 km E, Thomas R., 33°51'S 121°53'E, Britton, Taylor & Upton 20.11.1969 at light, beach dunes (24) ANIC; Fitzroy R., K. & E. Carnaby 16.4.1976 at light (7) ANIC; Fitzroy Crossing, K. & E. Carnaby 18.4.1976 at light (5) ANIC; Fremantle 10 km S, C. Watts 24.10.1996 (1) SAMA; Fremantle, North Lake, H. Demarz 30.1.1954 (2) FMNH; Geraldton 11 km N, N. McFarland 12.11.1972 UV light (3) ANIC; Hyden E, K. & E. Carnaby 5.2.1977 (1) ANIC; Julimar St. Forest, E. Matthews 9.10.1967 (2) ANIC; Kimberley E, Benn R., Helms (6) SAMA; Kimberley E, Upp. Ord R., Helms (1) Griffith Coll., SAMA; Kuliba, Ravensthorpe-Hopetoun, E. Britton 21.9.1965 (1) ANIC; Kununurra nr. Wyndham, Kimberley Research Station, 15°28'S 128°06'E, 27.XI.1956 (31) ANIC, MSNV; Kununurra, E. G. Matthews 13–22.2.1968 (1) ANIC; Kununurra 100 mi E, J. A. Mahon 27.3.1966, light trap (1) ANIC; Margaret R., roadside pond, E. Britton 29.9.1965 (1) ANIC; Mitchell Plateau, 14°40'S 125°44'E, B. V. Timms 23.9.1982 (1) SAMA; Mitchell Plateau, King Ed. R. crossing, Rd., J. B. Kethley 14.10.1976 at light (1) FMNH; Mitchell Plateau, Mining Camp, 14°49'S 125°50'E, Naumann & Cardale 9–19.5.1983 at light (7) ANIC; id., Rentz & Balderson 9–19.5.1983 on light sheet (5) ANIC; id. 3 km NW, 14°48'S 125°49'E, Rentz & Balderson 15.5.1983, airstrip (4) ANIC; id. 4 km S, 14°52'S 125°50'E, Rentz & Balderson 13.5.1983, crusher at light (17) ANIC; id. 10 km NW, 14°45'S 125°47'E, Rentz & Balderson 11–17.5.1983 (2) ANIC; Mowen 10 mi E, Margaret River, 33°57'S 115°34'E, E. Britton 14.11.1969 roadside pond (10) ANIC; Mt Arid 23 km NW, Thomas River 33°51'S 123°00'E, J. F. Lawrence 4–7.11.1977 (14) ANIC; Mt Chudalup St. Pk, North Cliffs 16 km S, J. Kethley 4.12.1976 wet moss on sand over seepage area (1) FMNH; Nannup, Augusta Rd., E. Britton 28.9.1965 (1) ANIC; Osmington 5 mi N, nr Margaret R., 33°57'S 115°04'E, E. B. Britton 15.11.1969 edge of roadside pool (3), under bark of recently felled trees (1) ANIC; Pago Mission 3 mi SE, J. B. Kethley 26.10.1976 at light (3), 27.10.1976 small pool (6) FMNH; Perth, Floreat Park, M. S. Upton 21.1.1967 (1) ANIC; Perth E, Orange Grove Caravan Pk Gosnells, Reid & Gullan 5.1.1986 at light (2) ANIC; Perth S, Yule Brook Univers. Res., C. Reid & P. J. Gullan 7–8.1.1986 at light (23) ANIC; Perth 30 km N, C. Watts 14.10.1996 (3) SAMA; Picton Junction, swamp nr Ferguson R., Britton & Uther Baker 30.11.1965 (16) ANIC; Pinjarra, Lea 1870 (10) SAMA; Pinjarra 8 mi E, South Dandalup R., 32°35'S 115°53'E, E. Britton 17.11.1969 clear brook flowing over stones (42) ANIC, MSNV; Pinjarra 6 km S, C. Watts 6.10.1996 (9) SAMA; Walpole Rd, Nornalup

Beach Rd, S. & J. Peck 20–26.6.1980, flight intercept traps (2) ANIC; Walsh Pt 5 km W, 14°34'S 125°48'E, Rentz & Balderson 10.5.1983 (2) ANIC; Wilga, K. & E. Carnaby 11.1973, 8.12.74 etc. (33) ANIC; William Bay, stream on road to, E. Britton 24.9.1965 (3) ANIC; Wyndham, K. & E. Carnaby 20.4.1976 at light (1) ANIC; Yanchep NP, Yanchep 9 mi N, Common & Upton 12.4.1968 (1) ANIC.

Biology

From label data I extracted the following indications about the habits of *P. pygmaeus*. Most specimens are collected in flight: at light, light trap, on light sheet, UV light, black light, flight intercept traps, window-trough traps. Another method is collecting along edges, shores or banks of brooks, creeks, rivers, pools, bogs, swamps, waterholes, ponds and lakes: in mud, sand, gravel, aquatic plants such as lilies, *Sphagnum*, moss, and lichens; more rarely in open water. Also, litter is a source of specimens: wet rotting wood, bark of fallen trees, leaves on forest floor, soil and grasses, floating debris. Exceptional captures are: from nest of buff-tailed thornbill; in flowers of *Hybiscus tiliaceus*; on *Acacia* spp.

2. *Paracymus spenceri* Blackburn, 1896

Paracymus spenceri Blackburn 1896: 256–257; d'Orchymont 1942: 59–60; Wooldridge 1976: 454–455; Hansen 1999: 114.

Paranacaena spenceri (Blackburn): Knisch 1924: 168.

Types

Lectotype male: **Northern Territory**: Paisley Bluff, Reedy Creek, Blackburn Coll. NHML. A single pin bears the following cards and labels: 1. Insect (and) I, 5480, Reedy Cr., male; 2. Aedeagus (on transparent card); 3. Type (round label with red border); 4. Australia, Blackburn Coll., B.M. 1910 – 236; 5. Paracymus spenceri Blackb.; 6. Paranacaena spenceri Blackb., LECTOTYPUS male, E. Gentili 1991, Aedeagus in DMHF soluble in distilled water. *Paralectotype*: **Northern Territory**: Paisley Bluff, Reedy Creek SAMA. A single pin bears: 1. Insect (dorsally glued, and) 5480, Reedy Creek; 2. Paracymus spenceri Blackb., co-type; 3. Paracymus spenceri Blackb., Paralectotypus, E. Gentili 1992 (red label); 4. S. A. Museum specimen (red label). The Blackburn description records four typical specimens from Paisley Bluff, Reedy Creek; I did not see other types.

Description

Length 1.5–2.3 mm; width 0.8–1.3 mm. Elongate oval, slightly convex (Figs 18, 19). Head black, sometimes with violet reflection, evenly punctured, surface shining between punctures, occipital region alutaceous; only lateral branches of Y-suture scarcely conspicuous. Pronotum dark as head, becoming yellow to mahogany at sides; punctation thicker than on head, surface shining between punctures. Elytra mahogany or red-brown, lighter near apical region; punctation as on pronotum but less evident, without serial arrangement; some specimens nevertheless have traces of serial punctures due to partial transparency of elytra; parasutural furrow in apical 2/3 of elytra or a bit less. Underside dark; prosternum with longitudinal keel; mesosternum carinate with an arrow-like keel; first visible abdominal ventrite laterally shorter than second, centrally with thin longitudinal keel. Maxillary palpi yellow, tips darker; antennae eight-segmented, yellow with darker club. Profemora ventrally pubescent on basal 3/4 (or 2/3), male protarsi with a blunt spine under last segment; mesofemora pubescent near base; metafemora without hydrofuge hairs. Aedeagus as in Figs 6–8, tegmen nearly as long as parameres, with a cardioid form; parameres progressively narrowing but slightly expanded laterally at their tip; penis roughly triangular, provided with a subapical collar.

Discussion

Easy to distinguish among Australian *Paracymus* by the contrasting colour of the pronotum/elytra. The male protarsus is thinner, and the profemoral pubescence thicker than in *pygmaeus*. The shape of the aedeagus is near to that of *pygmaeus*, but the outline of the tegmen and parameres is more curved, and the preapical collar lacks any membranous expansion.

Material examined (Fig. 23)

Australian Capital Territory: Black Mountain, I. F. B. Common 25–26.12.1964 light trap (1), 6.1.1966 light trap (1), M. S. Upton 22.12.1966 light trap (1) ANIC. **New South Wales**: Dorrigo NP, E end, Blackbutt Track 710 m, subtropical rainforest, Newton & Thayer 28.2–5.3.1980 in and under rotting fruits of *Endiandra introsa* (1) USNM; Nightcap NP, Mt Nardi, Newton Drive 700 m, warm-temperate rainforest, 28°33'S 153°17'E, Newton & Thayer 4.1.1987 Berlese leaf and log litter, forest floor (5) FMNH; Uki 18 km W, Mebbin St. For., J.

FIGURE 23. Distribution of the studied specimens of *Paracymus spenceri* Blackburn, 1896.

Doyen 23–24.11.1982 (1) ANIC. **Northern Territory**: Alice Springs 80 mi NW, C. Watts 2.1968 (5) SAMA; Alice Springs 5 mi N, Wigley Waterhole, Britton Upton & McInnes 16.2.1966 (2) ANIC; Alice Springs 6 mi SE, Emily Gap, Britton Upton & McInnes 17.2.1966 (2) ANIC; Alice Springs 9 km N, Todd R., 23°38'S 133°53'E, M. S. Upton 10.10.1978 (3) ANIC; Alice Springs 33 km WNW, 23°36'S 133°34'E, M. S. Upton 30.9.1978 (3) ANIC, MSNV; Alice Springs 99 km NE, Ongeva Ck, 23°01'S 134°29'E, M. S. Upton 13.10.1978 (1) ANIC; Batchelor 1 km SE, N. McFarland 12.4.1966 UV light (3) SAMA; Borroloola 11 km SW, Goose Lagoon, 16°10'S 136°15'E, J. E. Feehan 17.4.1976 at light (4) ANIC, MSNV; Borroloola 22 km WSW, 16°08'S 136°06'E, J. E. Feehan 16.4.1986 at light (1) ANIC; Borroloola 30 km NE, Batten Point, 15°54'S 136°32'E, J. E. Feehan 18.4.1976 (1) ANIC; Borroloola 31 km WSW, Batten Ck, 16°10'S 136°03'E, J. E. Feehan 15.4.1976 at light (1) ANIC; Borroloola 45 km SW, Surprise Ck, 16°25'S 136°05'E, J. E. Feehan 14.4.1976 at light (1) ANIC; Borroloola 48 km SW, McArthur R., 16°27'S 136°05'E, J. E. Feehan 13.4.1976 at light (1) ANIC; Edith Falls, J. C. Lesoeuf 8.7.1971 (1) ANIC; Mt Cahill 8 km N, Nourlangie Ck, 12°48'S 132°42'E, Upton & Feehan 16.6.1973 (1) ANIC; Renner Springs 4.6 km S, N. McFarland 8.3.1966 UV light (1) SAMA; Timber Ck 4 mi W, N. McFarland 14.4.1966 (2) SAMA; Wauchope 30 km N, 20°22'S 134°14'E, M. S. Upton 13.10.1972 (5) ANIC, MSNV. **Queensland**: Archer R., C. Watts 28.10.1984 (1) SAMA; Barkley Hwy 7 mi N, on Burketown Rd, J. A. Forrest 23.9.1977 burnt out area some regrowth, at light (1) SAMA; Cairns, Edge Hill, J. G. Brooks 11.11.1967 (1) ANIC; Cardstone, K. Hyde 9–13.3.1966 (3) ANIC; Cooktown Rd 75 km, Boggy Ck, E. B. Britton 26.4.1976 (3) ANIC; Eidsvold N, Burnett R., 24°46'S 152°25'E, Britton. Holloway & Misko 10.1.1970 at light (2) ANIC; Forty Mile Scrub Nat. Pk, Mt Garnet 52 km SW, 18°05'S 144°52'E, Weir & Calder 21.7.1986 (2) ANIC; Funnel Ck 21°47'S 148°55'E, Britton & Misko 12.12.1968 at light (4) ANIC, MSNV; Ingham 23 mi SSE, Crystal Ck, 18°58'S 146°16'E, Britton & Misko 9.12.1968 at light (2); Laura, C. Watts 18.7.1982 (2) SAMA; Monto 22 km NW, Coominglah St. For., J. T. Doyen 23.12.1982 (1) ANIC; Mornington Island Mission, Aitken & Tindale 11.5.1963 at light (1) SAMA; Normanton, Tindale & Aitken 4.5.1963 at light (1) SAMA; Pentland, J. C. Lesoeuf 12.7.1975 (1) ANIC; Station Ck, J. G. Brooks 19.4.1970 (3) ANIC; Townsville, P. Ferrar 19.11.1967 light trap (1) ANIC; Tully 40 km W, E. F. Riek 31.5.1971 (3) ANIC, MSNV. **South Australia**: Chambers Gorge, C. Watts 9.1983 (5) SAMA; Enorama Ck, Amena Valley Rd, Nth. Flinders, Suter Mitchell & Marchant 26.7.1976 (1) SAMA; Flinders Ra., Arkaba Ck, E. G. Matthews 5.3.1973 (10) SAMA, MSNV; Flinders Ra., Blinman 12 km NW, I & II springs, J. A. Forrest 10.5.1981 (2) SAMA; Flinders Ra., Brachina Ck nr. Heysen Hill, J. A. Forrest 9.5.1981 (1) SAMA; Flinders Ra., Eringunda V., E. G. Matthews 6.3.1973 (2) SAMA; Flinders Ra., Parachilna Gorge, C. Watts 10.1981 (1) ANIC; Flinders Ra., Wooltana HS 6 km SW, Munyallina Ck, J. A. Forrest 12.5.1981 (1) SAMA; Manu Ra., Angatja homestead 5 km N, damp litter, L. E. Watrous 11.5.1983 (3) FMNH; Mt Remarkable, L. E. Watrous 29.4.1983 black light (1) FMNH; Musgrave Ra., Ernabella 13 km N, L. E. Watrous 7.5.1983 (12) FMNH; Musgrave Ra., Rock Hole, SSE Mt Woodruffe, L. E. Watrous 8.5.1983 black light (7) FMNH; Owieandana, N Flinders Ra., Hale & Tindale (2) SAMA; Parachilna, Flinders Ra., Griffith Coll., (1) SAMA; Quorn 30 km NNW, Buckaringa Gorge, C. Reid 18.12.1985 (2) ANIC; Woodendina Ck, Nirrana, Flinders, Bishop & Diener 16.12.1976 (4) SAMA, MSNV. **Victoria**: Turtons Track, Otway Ranges, Gross & Aitken 17.1.1962 (1) SAMA. **Western Australia**: Beverley, Griffith Coll. (7) SAMA, MSNV; Cane River HS. 17 km N, 21°56'S 115°39'E, Upton & Mitchell 27.4.1971 (5) ANIC, MSNV; Carson Escarpment, 14°49'S 126°49'E, Common & Upton 9–15.8.1975 (7) ANIC, MSNV; Dampier, Dampier Is., Intercourse, pool standing water, J. B. Kethley 2.10.1976 (2) FMNH; Derby, W. D. Dodd (1) SAMA; Kimberley Bore, K. & E. Carnaby 13.3.1980 at light (1) ANIC; Kimberley W, Cape Bertholet 8 km S, 17°19'S 122°10'E, D. H. Colless 19.4.1977 (1) ANIC; Millstream, 21°35'S 117°04E, E. B. Britton 28.10.1970 at light, open eucalypt paperbark woodland (2) ANIC; 28.10.1970 at light, open eucalypt-paperbark woodland kangaroo grazed grass (1) ANIC; 28.10.1970 Crystal Pool (4) ANIC; 29.10.1970 shallow stream (18) ANIC; 29.10.1970 at light spinifex-eucalypt junction (22) ANIC; 30.10.1970 eucalypt-spinifex (2) ANIC; 31.10.1970 (10) ANIC; 1.11.1970 gravel at margin of Crossing Pool (24) ANIC; 2.11.1970 from gravel at edge of pool at pipe crossing (82) ANIC, MSNV; 1.11.1970 at light, eucalypt-paperbark woodland (1) ANIC; 2.11.1970 palm-eucalypt-melaleuca assocn, at light (6) ANIC; 3.11.1970 shallow weed-grown pool (2) ANIC; 3.11.1970 at light (28) ANIC; 4.11.1970 Crossing Pool, at light (1) ANIC; 5.11.1970 waterside gravel in pipe, Crossing Pool (16) ANIC; 5.11.1970 eucalypt-spinifex, at light (2) ANIC; 5.11.1970 Crystal Pool, at light (14) ANIC; 7.11.1970 mouth of Dawson's Ck (17) ANIC; 8.11.1970 Deep Reach, at light (3) ANIC; Millstream, Crossing Pool, D. H. Colless 21.10.1970 (2) ANIC; Millstream HS, E. F. Riek 4.4.1971 (5) ANIC; Millstream HS. ½ km WNW, 21°35'S 117°04'E, M. S. Upton 21.10.1970 (4), Upton & Mitchell 14.4.1971 (24) ANIC, MSNV; Millstream 1 km NE, 21°35'S 117°04'E, M. S. Upton 24.10.1970 (14) ANIC; Millstream 1 km NNE, M. S. Upton 3–4.4.1971 (14) ANIC; Millstream 1 km N, M. S. Upton 9–10.4.1971 (3) ANIC; Millstream 2 km ENE, M. S. Upton 21.10.1970 (1) ANIC; Millstream HS. 3 km NW, 21°34'S 117°03'E, Upton & Mitchell 22.4.1971 (7) ANIC; Millstream HS. 5 km SE, 21°37'S 117°06'E, Upton & Mitchell 17.4.1971 (1) ANIC; Millstream 8 mi ENE, D. H. Colless 20.10.1970 (5) ANIC; Millstream 15 km E, 21°35'S 117°12'E, M. S. Upton 20.10.1970 (8) ANIC; Minilya R., 23°49'S 114°00'E, Upton & Mitchell 29.3.1971 (14) ANIC, MSNV; Mitchell Plateau, Mining Camp, 14°49'S 125°50'E, Rentz & Balderson 9–19.5.1983 (1) ANIC; id., 4 km S, 14°52'S 125°50'E, Rentz & Balderson 13.5.1983 (1) ANIC; Mt Magnet, K. & E. Carnaby 28–29.9.1978 (1) ANIC; Newman 13 km E, 23°15'S 119°52'E, E. B. Britton 12.11.1970 (8) ANIC; Walsh Pt 8 km SW, Escarpment, 14°37'S 125°48'E, Rentz & Balderson 10–17.5.1983 (1) ANIC; Wittenoom 13 km ESE, 22°18'S 118°27'E, E. B. Britton 11.11.1970 (1) ANIC.

Biology

The label data are scarcer than for *pygmaeus*, but similar. The species is collected most frequently at light (also UV light, black light), then at edge of standing or flowing water, e.g. in gravel, and occasionally in damp leaf and log litter on the forest floor. An exceptional capture is in and under rotting fruits of *Endiandra introsa*.

3. *Paracymus gigas* Gentili, 1996

Paracymus gigas Gentili 1996: 178; Hansen 1999: 111.

Types (Fig. 24)

Holotype male: **Western Australia**: Mitchell Plateau, Amax Warrender Rd 3 mi W, J. B. Kethley 21.10.1976, spring pool drainage, FMNH.

Description

Length 3.0 mm, width 1.8 mm. Convex, widely oval, black. Head 1.5 x as wide as long, black, densely punctured, interspaces once to twice width of punctures; anterior margin of labrum uniformly curved; eye/interocular space ratio nearly 0.7. Pronotum black with testaceous lateral margins, sides strongly curved; densely punctured as head, between punctures slightly shagreened. Scutellum black, trapezoidal, elongate, slightly protruding anteriorly. Elytra black, pale near lateral borders, with normally developed parasutural furrows, punctures somewhat denser than on pronotum and head, shagreened between punctures. Postlabium rectangular, flat and smooth; antennae 9-jointed; maxillary palpi long 0.6 x width of head; eyes large below. Prosternum with longitudinal keel; mesosternum with arrow-head-like keel; metasternum raised in middle, with conspicuous triangular dimple in raised area; abdominal ventrites pubescent. Profemora ventrally pubescent, mesofemora so only on and near trochanters, metafemora glabrous. Aedeagus as in Figs 11, 12: tegmen pointed at base, longer than parameres, ventrally protruding and covering base of penis with a jut; parameres blunt at apex and interiorly scythed; penis progressively constricted from base to apex, this slightly expanded as a button.

Discussion

Larger than all described Australian *Paracymus*, this species is immediately identified by its long maxillary palps, the 9-segmented antennae, and the metasternal dimple. The length of the palps and the shape of the aedeagus (e.g. tegmen with a

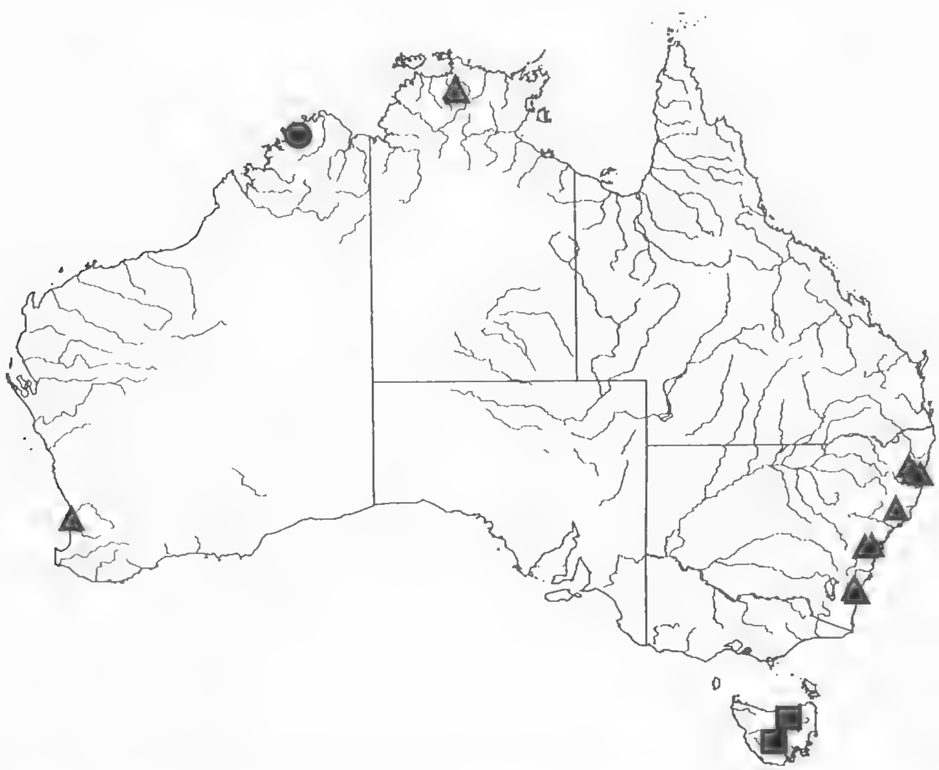


FIGURE 24. Distribution of the studied specimens of *Paracymus wattsi* n. sp. (▲), *cariceti* n. sp. (■), *gigas* Gentili, 1996 (●).

ventral jut covering the base of the penis) might suggest that it belongs to the genus *Notohydrus*; but the longitudinally keeled prosternum suggests the genus *Paracymus*.

4. *Paracymus cariceti* n. sp.

Types (Fig. 24)

Holotype male (1.7 x 1.1 mm): **Tasmania**: 42°32'S 146°30'E, Map 8212.593.923, Adj. Misery Creek 780 m, 21.2.1980, L. Hill coll., short sedge and rush turfs, ANIC, CSIRO. *Paratype*: **Tasmania**: male (without aedeagus, previously lost): Tasmania, Launceston, SAMA. Another specimen in SAMA, a female, labelled 'Launceston, Tas., Jan., C. Watts', might belong to this species, but apart from the slightly greater size it has the first abdominal segment with a longitudinal keel, lacking in the two typical males.

Description

Length 1.7–1.8 mm; width 1.0–1.1 mm. Widely oval, slightly convex. Dorsally black, head with metallic reflections, pronotal borders and elytral apex darkly testaceous. Labrum centrally hollow; anterior margin of clypeus straight; head, under 100 x magnification, slightly shagreened, with scarcely visible punctures; interocular space 3.6 x eye width. Pronotum smooth, with sparse punctures clearly visible at 100 x magnification, space between them nearly as large as punctures. Scutellum triangular, equilateral, smooth, with scarce and fine punctures. Elytra smooth, with a more or less faint shagreen at 100 x, with sparse punctures as on pronotum; parasutural furrow in apical 2/3 or a bit less. Underside testaceous, head black. Postlabium nearly rectangular, flat, smooth and shining; gula smooth. Prosternum carinate with a high longitudinal keel; mesosternum anteriorly provided with transverse tooth, and posteriorly with longitudinal keel; metasternum concealed under recumbent hairs. Five visible abdominal ventrites, glabrous and smooth, the first being the shorter, the last the longer; first ventrite without a longitudinal keel but with scarcely visible tubercle along central line; if specimen from Launceston previously recorded belongs to this species, female has a keel on first ventrite. Palps short and stout; profemora pubescent along anterior margin; mesofemora pubescent to knees; metafemora with scarce hairs near trochanters. Aedeagal length (Fig. 9) between 1/3 and 1/4 of body; tegmen narrow at its base, much shorter than parameres; these acute and longer than penis; penis basally swelling, then rod-like, anchor-shaped at tip, without any collar.

Discussion

This Tasmanian species differs from other Australian *Paracymus* chiefly by its aedeagus, which has the tip of the penis anchor-shaped at the apex, and the apex of the parameres acute. Other unique characters are the mesofemur which is completely pubescent on its ventral face, and the first ventrite having a tubercle instead of a longitudinal keel. Size and colour are similar to small *P. pygmaeus*; but it differs from this species in the aedeagus, which has a shorter tegmen, and the features mentioned; in its shorter and wider body shape; in its shorter and stouter palps; and in having the first abdominal segment not keeled.

Biology

The name *cariceti* comes from a label note: short sedge and rush turfs.

5. *Paracymus ovum* n. sp.

Types (Fig. 25)

Holotype male (2.8 x 1.45 mm): Kalbarri Nat. Pk, Northampton 54 mi N, Common & Upton 19.4.1968, ANIC; *paratypes* (3): same data as the holotype, ANIC, SAMA, MSNV.

Description

Length 2.5–2.8 mm; width 1.35–1.45 mm; elongate oval, slightly convex (Figs 18, 19). Head black, irregularly punctured, interspaces alutaceous or smooth, as large or larger than punctures, these less strong and deep than in *weiri*; labrum nearly concealed under head; eyes together as wide as nearly 4/7 of interocular space; Y-suture conspicuous only as periocular groove. Pronotum black with thin testaceous lateral border; punctures irregularly distributed as on head, a little more faint, interspaces alutaceous (chiefly on borders) or smooth (chiefly on disc); anterior corners clearly produced. Scutellum triangular, longer than wide. Elytra black with thin testaceous border; punctured as on pronotum, partly alutaceous; parasutural furrow in apical 2/3 or a bit less. Underside dark; postlabium smooth with small punctures; prosternum roof-like, keeled; mesosternal keel anteriorly like an arrow-head; metasternum posteriorly with glabrous area surrounded by tufts of hairs; first abdominal ventrite centrally covered with flat longitudinal keel, enlarging anteriorly. Palps yellow, second joint enlarged, last joint more slender than in *weiri*; antennae 8-segmented, yellow with a dark club. Profemora widely hairy, mesofemora only on basal third, metafemora glabrous. Aedeagus (Fig. 17) concave at base, tegmen nearly as long as parameres, these blunt at apex; penis rod-like with small subapical expansion or collar.

Discussion

Only the shape of the aedeagus differentiates *ovum* from all other Australian *Paracymus*; other differences are combinations of characters. It is similar to *weiri*, but differs in having a more slender, nearly parallel-sided body (Figs 18, 19); an upperside partly alutaceous; a flat keel on the entire first ventrite; a different aedeagus: tegmen shorter (in *weiri* it is longer than parameres, in *ovum* subequal), and penis less stout.

6. *Paracymus wattsi* n. sp.

Paracymus phalacroides Wooldridge 1978: 129; Hansen 1999: 112.

Types (Fig. 24)

Holotype male (1.7 x 1.0 mm): **New South Wales**: Barrington, NSW, 17.8.1997 C. Watts, SAMA; aedeagus preserved in DMHF. *Paratypes:* **New South Wales**, same data (2 females) SAMA; Batemans Bay 2 km N, C. Watts 18.4.1997 (5 males 3 females) SAMA, MSNV; Blue Mountains, Faulcon Bridge 500 m, G. Wewalka 15.1.1993 (1male 2 females) NMW, MSNV; Cabbage Tree Creek, Nelligan 20 km W, C. Watts 30.11.1995 (1male) SAMA; Dorrigo, W. Heron (1 female) ANIC [*Paracymus phalacroides*? det. D. P. Wooldridge]; Failford 8 km N, C. Watts 18.8.1997 (2 males 1 female) SAMA, MSNV; Valery, A. P. M. *Eucalyptus* plantation, McMullen's Block, 30°24'S 152°57'E, light trap, R. S. McInnes 10.1.1967 (4) ANIC, MSNV; Windsor, A. M. Lea 1871, Griffith Coll. (17) SAMA, MSNV. **Northern Territory**: Jabiru 10 km SW, C. Watts 22.3.1998 (1) SAMA; Gubara 1 km W, Kakadu NP, C. Watts 17.3.1998 (1 male) SAMA. **Western Australia**: Fremantle 10 km S, C. Watts 24.10.1996 (1) SAMA.

Description

Length 1.6–1.9 mm; width 1.0–1.1 mm. Body convex, short oval (Figs 20, 21), entirely black, only tips of palps and legs reddish. Head shining, smooth, only occipital region alutaceous, evenly punctured, intervals between punctures large, nearly twice as large as the punctures. In frontal view one eye measures nearly 1/6 of interocular space. Pronotum black, shining, smooth, evenly punctured as on head; at 100 x bottoms of punctures are umbilicate or jutting. Anterior margin of pronotum protruding in centre and laterally; lateral margin arched so that posteriorly pronotum enlarges. Scutellum triangular, slightly elongate, with curved sides, faintly punctured. Elytra short, their maximum width at anterior third; punctures denser than on pronotum, at 100 x umbilicate or rugose, evenly distributed; surface slightly alutaceous between punctures; parasutural furrow on apical 2/3 or a bit less. Underside black. Labrum arched, slightly hollow at centre; postlabium flat or convex, alutaceous at 100 x with scarce and faint punctures. Gula alutaceous, with two furrows and two deep punctures. Prosternum tectiform, keeled; mesosternum with longitudinal keel anteriorly expanded; metasternum punctured and pubescent, elevated in centre, slightly hollow and posteriorly produced. Five visible abdominal sternites, micropunctured, not keeled; pygidium with a dozen stiff and short setae directed posteriorly and centrally. Profemora excavated, granulose and hairy on basal 2/3; mesofemora hairy on basal 3/4; metafemora smooth, with sparse hairs. Tibiae shorter than femora, spiny at their margins; tarsi not expanded in male, claws hooked. Aedeagus (Fig. 15) nearly 1/4 as long as body; tegmen shorter than parameres, narrow and pointed at base; parameres slender, with rounded apices; penis conical, pointed, without any collar.

Discussion

Characters of the species distinguishing it from all Australian *Paracymus* are the umbilicate punctures, the copious hydrofugal hairs at the base of the mesofemora (only *cariceti* has more), the lack of any keel on the first ventrite (as in *cariceti*, which however has a tubercle instead of a keel), and the aedeagus (penis triangular to the apex, tegmen abruptly pointed). From *pygmaeus* it is also separated by the small size, the short and convex body (length:width 1.7 in *pygmaeus;* 1.6 in *wattsi*). With *opacus, australiae* and *weiri* it constitutes a group of short and convex *Paracymus* (Figs 20, 21). Wooldridge 1978 records two females of this species (SAMA; now 1 in ANIC) as possibly belonging to the palaearctic *P. phalacroides* (Wollaston, 1867). But the punctures of *phalacroides* are geminate, not umbilicate as in *wattsi*; the mesosternal keel of *phalacroides* is very low, in *wattsi* normally shaped; and the bases of the parameres are internally excavated in *phalacroides*, swollen in *wattsi*.

Biology

One label has the note: light trap. C. Watts captured his specimens 'in thick grassy vegetation at edge of water in large swampy areas' (personal communication).

7. *Paracymus opacus* n. sp.

Types (Fig. 25)

Holotype male (1.7 x 1.0 mm): **Queensland**, Bentinck Is. Minakuri, Aitken & Tindale 23.5.1960 at light, SAMA. *Paratypes*: **Queensland**: Bentinck Is. Minakuri, Aitken & Tindale 23.5.1960 at light (4) SAMA, MSNV; Paluma Dam Road, J. G. Brooks 13.1.1968 (1) ANIC; Seaforth 1 km NW, 20°53'S 148°57'E, A. Gillison 18.11.1981 Berlesate, Melaleuca woodland (1) ANIC; Stewart R., W. D. Dodd (3) SAMA, MSNV; Townsville 20 km N, Bushland Beach, A. J. Watts 6–11.2.1998 (2) SAMA.

Description

Length 1.6–2.0 mm; width 0.95–1.2 mm. Body convex, short, oval (Figs 20, 21), entirely black. Upper body entirely alutaceous, satiny, impunctate. Head grey-black, satiny like pronotum and elytra, branches of Y-suture conspicuous. Pronotum enlarged posteriorly. Scutellum triangular, impunctate. Elytra with parasutural furrow in apical 2/3 or a bit less. Underside black or dark brown; postlabium flat, alutaceous, impunctate; prosternum short, roof-like, with a longitudinal keel; mesosternal keel short, ending anteriorly close to a high transverse ridge; metasternum hairy, elevated in middle as a flat triangle posteriorly acute. First abdominal ventrite with a median keel, rising from a central process protruding anteriorly. Antennae 8-segmented; basal 2/3 of profemur densely pubescent, protibiae and protarsi short and thick, last tarsal segment with a small denticle in males; claws short and hooked. Aedeagus (Fig. 16) with a very long tegmen, penis rod-like, anchor-shaped at tip, parameres provided with a triangular membrane, progressively expanded from base to apex.

Discussion

Among Australian *Paracymus*, *opacus* differs in having a strongly alutaceous and impunctate upperside, a flat hairy triangular prominence on the metasternal surface, and a very unusual aedeagus: tegmen more than twice as long as the length of the parameres, which are expanded towards the penis by a membrane. It is very near *P. wattsi* in body form and size, but is easily separated by the preceding characters.

Biology

Four specimens captured at light, one from forest floor litter, with Berlese funnel.

8. *Paracymus australiae* n.sp.

Types (Fig. 25)

Holotype male (2.3 x 1.4 mm): **Northern Territory**: Oenpelli 6 km SW by S, 12°22'S 133°01'E, E. G. Matthews 30.5.1973 at light, ANIC. *Paratypes*: **Northern Territory**: Baroalba Spring, 12°47'S 132°51'E, 20.11.1972 (1) ANIC; Borroloola 46 km SSW, 16°28'S 136°09'E, J. E. Feehan 23.4.1976 (6) ANIC, SAMA, MSNV; Borroloola 48 km SW by S, McArthur R., 16°27'S 136°05'E, J. E. Feehan 13.4.1976 at light (1) ANIC; Cahills Crossing 1 km S, E Alligator R., 12°26'S 132°58'E, E. B. Britton 3.11.1972 at light (1) ANIC; Cape Crawford 8 km ESE, Bessie Spring, 16°40'S 135°51'E, M. S. Upton 26.10.1975 (1) ANIC; Mt Cahill 8 km E, Nourlangie Ck, 12°52'S 132°47'E, E. B. Britton 27.10.1972 at light (1) ANIC; Mt Cahill 15 km E by N, 12°50'S 132°51'E, E. B. Britton 29.10.1972 at light (4) ANIC, SAMA, MSNV; Mt Cahill 15 km E Koongarra, 12°52'S 132°50'E, M. S. Upton 15.11.1972 (5), 6–10.3.1973 (3) ANIC, SAMA, MNSV; Mudginbarry HS 9 km N by E, 12°31'S 132°54'E, Upton & Feehan 10.6.1973 (3) ANIC, SAMA, MSNV; Oenpelli 6 km SW by S, 12°22'S 133°01'E, Upton & Feehan 6.6.1973 (1) ANIC.

Description

Length 2.0–2.5 mm; width 1.35–1.5 mm; short, oval, slightly convex. Upper side black with dark testaceous contour zone; head, pronotum and elytra coarsely punctate, space between punctures nearly as large as punctures; each puncture larger than those of *P. pygmaeus*. Head entirely black, anteriorly slightly hollow in centre to receive labium; sutures not conspicuous; eyes large, together nearly 6/10 width of interocular space. Pronotum anteriorly slightly curved, with notably prominent corners, much larger at base (ratio hind width : fore width 1.65); black with brown sides, evenly punctured as on elytra. Elytra, observed from above, nearly as long as wide (ratio elytral

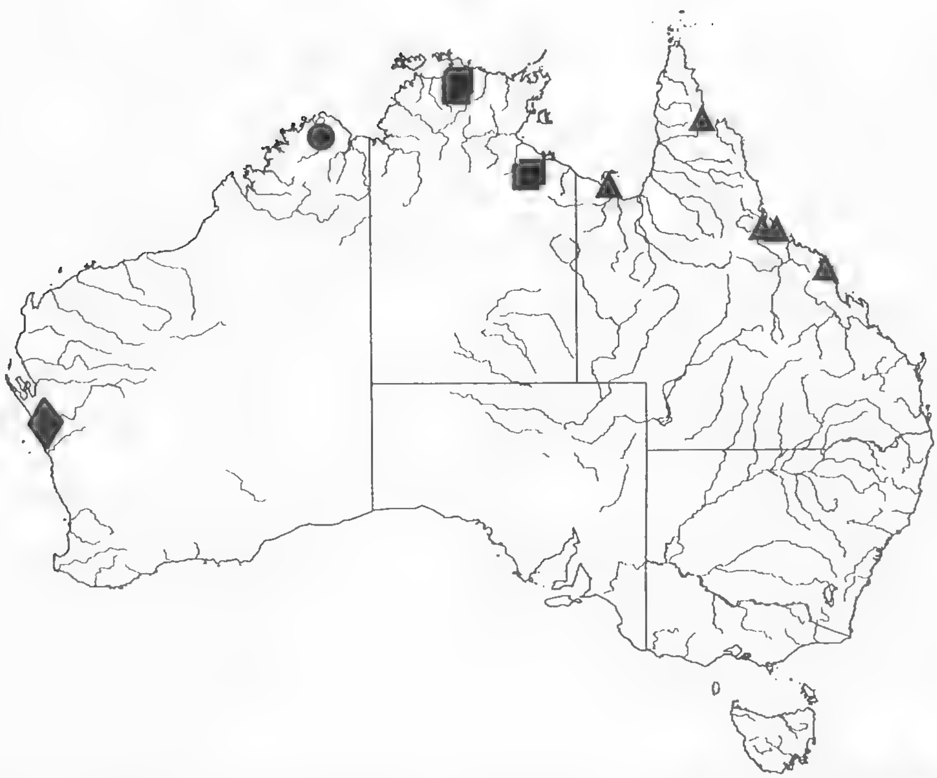


FIGURE 25. Distribution of the studied specimens of *Paracymus opacus* n. sp. (▲), *australiae* n. sp. (■), *weiri* n. sp. (●), and *ovum* n. sp. (♦).

length : elytral width 1.07); parasutural furrow in apical 3/4 or a bit less; black with brown sides and apex. Underside dark, brown to reddish; labrum of male with two small specula, postlabium flat, slight and shining; prosternum roof-like, with longitudinal keel; a fine mesosternal keel anteriorly reaches a robust crescent-shaped ridge; metasternum hairy, two reliefs provided with tufts of setae delimiting a central glabrous area; first abdominal ventrite keeled on anterior 1/2–1/3. Palps yellow, antennae 8-segmented; profemora hairy on basal 3/4, male protarsi with a robust seta or tooth; mesofemora with hydrofuge hairs on a large postero-basal area; metafemora glabrous. Aedeagus (Fig. 10) long, nearly 3/10 of body length, tegmen constricted near base, bluntly pointed, longer than parameres, these blunt at apices, penis nearly triangular, gradually narrower from base to apex, without any collar.

Discussion

Among the Australian *Paracymus*, some features are exclusive to *australiae*: the great length of the parasutural furrow, the coarse dorsal punctation with large punctures, the male specula, the two hairy metasternal reliefs, and the first ventrite, which is keeled only anteriorly. This species is distinguishable from *pygmaeus* also by the stocky body shape, and by the aedeagus being more slender, straightened basally, with penis gradually narrowing, not suddenly restricted in the apical zone, unprovided with a collar.

Biology

Some specimens were captured at light, others in standing or flowing water.

9. *Paracymus weiri* n. sp.

Types (Fig. 25)

Holotype male (2.9 x 1.7 mm): **Western Australia**: Carson Escarpment, 14°49'S 126°49'E, Common & Upton 9–15.8.1975 ANIC. *Paratypes*: **Western Australia**: Carson Escarpment, 14°49'S

126°49'E, Common & Upton 9–15.8.1975 (9) ANIC, SAMA, MSNV.

Description

Length 2.3–3.0 mm, width 1.5–1.8 mm; short oval, convex. Head black, evenly punctured, interspaces smooth, nearly as large as punctures; anteriorly a central hollow receives labrum; eyes slightly protuberant, their width together nearly 2/3 of interocular space; Y-suture reduced to an incomplete periocular groove. Pronotum and elytra black with lateral margins and apex testaceous-reddish, punctured as on head or more deeply; elytra with parasutural furrow in apical 2/3 or a bit less; scutellum triangular, slightly elongate, punctured. Underside dark. Postlabium flat and smooth; prosternum evidently keeled; mesosternum with a longitudinal keel ending anteriorly as an arrow-head; metasternum glabrous in centre, the glabrous area delimited by two hairy lines converging posteriorly. First abdominal ventrite with a high keel almost reaching posterior margin. Palps and antennae (8-segmented) yellow with dark tips; legs dark; profemur pubescent nearly to the knees, last segment of male protarsi with two little teeth; mesofemora pubescent for nearly 2/3 of posterior margin. Aedeagus as in Figs 13, 14: tegmen concave at base, longer than parameres; these blunt at apices; penis conical, stout, provided with a preapical expansion or collar.

Discussion

Considering the body shape, *P. weiri* belongs to the group containing *wattsi*, *opacus*, and *australiae* (Figs 20, 21); the outline of the aedeagus recalls *P. ovum*. The body shape and upper punctation are similar to *P. australiae*, but *weiri* is larger in size and not provided with male specula; it has the first abdominal ventrite with a high keel and a very different aedeagus: base of tegmen concave (in *australiae* bluntly pointed), penis abruptly expanded before the apex (in *australiae* uniformly conical).

A Key To The Australian *Paracymus*

1. — Elytral colour mahogany or testaceous brown; pronotum black. Aedeagus as in Figs 6–8: tegmen pointed at base, penis with a simple preapical collar, external border of parameres evenly curved. Elongate oval (Figs 18, 19). Length 1.5–2.3 mm .... *spenceri* Blackburn

— Pronotum and elytra black. Aedeagus with different combination of characters: base of tegmen concave, or penis without a simple preapical collar, or parameres externally straight 2

2. — Male protarsus swollen, last segment evidently thicker than in female, proclaws spatulate, inner one stronger than outer. Aedeagus as in Figs 1–5: base of tegmen pointed, penis with a preapical collar originating a basal membrane, parameres externally straight. Elongate oval (Figs 18, 19). Length 1.6–3.0 mm .... *pygmaeus* (McLeay)

— Male protarsus not or only a bit swollen. Aedeagus without a preapical collar originating a membrane 3

3. — Upper side impunctate and strongly alutaceous, satiny. Aedeagus as in Fig. 16: a very long tegmen (more than 2 x the length of parameres), penis rod-like, anchor shaped at apex, parameres internally originating as a membrane. Short oval, convex (Figs 20, 21). Length 1.6–2.0 mm .... *opacus* n. sp.

— Upper side punctured, smooth or moderately alutaceous. Tegmen shorter, parameres without any membrane 4

4. — Dorsal punctures (magnification 100 x) umbilicate or with a jut in the bottom. First abdominal ventrite not keeled nor tuberculate. Short, widely oval, convex (Figs 20, 21). Aedeagus as in Fig. 15: tegmen sharply pointed, penis conical, without any collar. Length 1.6–1.9 mm. .... *wattsi* n. sp.

— Dorsal punctures simple, not umbilicate. First abdominal ventrite keeled or tuberculate. Tegmen never sharply pointed 5

5. — Antennae 9-segmented. Maxillary palps long, 0.6 x width of head. Dorsal surface slightly shagreened. Metasternum with a conspicuous triangular dimple. Aedeagus as in Figs 11, 12: tegmen provided with a central jut covering the base of the penis. Length 3.0 mm .... *gigas* Gentili

— Antennae 8-segmented. Maxillary palps shorter than 0.5 x the width of head. Metasternum without any dimple. Tegmen simple, without any jut anteriorly protruding 6

6. — Parasutural furrow covering nearly 3/4 of elytral length. Upper side coarsely punctured with large punctures. Male labrum with small specula. Only anterior 1/2–1/3 of the first ventrite keeled. Aedeagus as in Fig. 10: base of tegmen bluntly pointed, penis simply conical. Length 2.0–2.5 mm ..... *australiae* n. sp.
   — Parasutural furrow covering nearly 2/3 of elytral length. Labrum without specula. First ventrite not or differently keeled. Apex of penis anchor-shaped 7
7. — Whole ventral surface of mesofemora pubescent. First ventrite tuberculate along the median line. Aedeagus bluntly pointed at base, penis with apical anchor, apices of parameres acute (Fig. 9). Length 1.7–1.8 mm .... *cariceti* n. sp.
   — At least apical 1/3 of mesofemora glabrous. First ventrite keeled. Aedeagus concave at base, penis with preapical expansion, apices of parameres blunt 8
8. — First ventrite completely carinate with a flat longitudinal keel. Dorsal punctures more feeble. Elongate oval (Figs 18, 19). Aedeagus as in Fig. 17: tegmen nearly as long as parameres, penis more thin, rod-like, with feeble preapical expansions. Length 2.5–2.8 mm .... *ovum* n. sp.
   — First ventrite with a high keel not covering whole segment. Dorsal punctures stronger. Short oval (Figs 20, 21). Aedeagus as in Figs 13, 14: tegmen longer than parameres, penis more stout, subconical, with strong preapical expansions. Length 2.3–3.0 mm .... *weiri* n. sp.

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I wish to thank Manuela Caccia (Milano) for the drawings, Tom Weir of the CSIRO (Canberra) for the maps, Chris Watts of the South Australian Museum (Adelaide) for information, useful suggestions and communication of rare specimens, R. G. Ordish (Wellington), E. G. Matthews (Adelaide), F. Hebauer (Grafling) for advice, and the following persons for their kindness in procuring types or other material: E. G. Matthews (SAMA), T. Weir (ANIC), R. Brett and D. Kavanaugh (CASF), A. Newton and M. Thayer (FMNH), K. Desender (ISNB), S. J. Hine (NHML), M. Jäch (NMW), P. Spangler (USNM).

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A NEW SPECIES OF THE GENUS *LESTIGNATHUS* ERICHSON FROM TASMANIA WITH A NOTE ON THE TASMANIAN SPECIES OF *MECYCLOTHORAX* SHARP (INSECTA: COLEOPTERA: CARABIDAE: LICININAE, PSYDRINAE).

BY MARTIN BAEHR

Summary

BAEHR, M. (2000). *Lestignathus pieperi*, sp. nov. is described from Mt Field, southwestern Tasmania. It is distinguished *inter alia* from the three known species of the genus *Lestignathus* by presence of only one setiferous puncture on the 3rd interval. A key to all species of the genus is added.

A NEW SPECIES OF THE GENUS *LESTIGNATHUS* ERICHSON FROM TASMANIA WITH A NOTE ON THE TASMANIAN SPECIES OF *MECYCLOTHORAX* SHARP (INSECTA: COLEOPTERA: CARABIDAE: LICININAE, PSYDRINAE)

MARTIN BAEHR

BAEHR, M. 2000. A new species of the genus *Lestignathus* Erichson from Tasmania, with a note on the Tasmanian species of *Mecyclothorax* Sharp (Insecta: Coleoptera: Carabidae: Licininae, Psydrinae). *Records of the South Australian Museum* **33**(2): 123–126.

Lestignathus pieperi, sp. nov. is described from Mt Field, southwestern Tasmania. It is distinguished *inter alia* from the three known species of the genus *Lestignathus* by presence of only one setiferous puncture on the 3rd interval. A key to all species of the genus is added.

Recent collections revealed that in Tasmania two species of *Mecyclothorax* occur, namely the well-recorded *M. ambiguus* (Erichson), and *M. punctipennis* (Macleay) that is widespread on the mainland but not previously recorded from Tasmania.

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INTRODUCTION

Through the kindness of Dr Harald Pieper (Kiel) I received a sample of Tasmanian Carabidae for identification that he collected mainly in western Tasmania during a trip in December 1998. This sample included, *inter alia*, a new species of the licinine genus *Lestignathus* Erichson, as well as the first Tasmanian record of the psydrine species *Mecyclothorax punctipennis* (Macleay). By courtesy of Dr Eric Matthews, Adelaide, I had the opportunity to compare types or material of all described species of *Lestignathus* stored in the collection of the South Australian Museum.

So far, the genus *Lestignathus* Erichson includes three rather different species (Sloane 1920, Moore *et al.* 1987) that all occur in Tasmania, namely the common and widespread, large *Lestignathus cursor* Erichson, and the apparently much rarer, smaller species *L. foveatus* Sloane and *L. simsoni* Bates. The new species differs from all described species in several respects, hence description of the single known specimen seems advisable, the more so as all species of *Lestignathus*, except for *L. cursor*, apparently are rare or very rare, and additional material is unlikely to be detected soon.

MEASUREMENTS

Measurements have been made under a stereo microscope by use of an ocular micrometer. Length has been measured from apex of labrum to apex of elytra. Length of pronotum was taken from the most advanced tip of anterior angles to the most advanced part of base. Width of base was taken at position of the posterior marginal setae. Measurements, therefore, may slightly differ from those of Sloane (1920).

LOCATION OF TYPES

To facilitate further study of the genus *Lestignathus*, the holotype of *L. pieperi* sp. nov. is presented to the South Australian Museum. Therefore, the types of three of the four recorded species of the genus *Lestignathus* are assembled in that collection which also holds historical material of the fourth species.

Lestignathus pieperi sp. nov.
(Figs 1–2)

Holotype: f, TAS, Mt Field Lyrebird Nat. Walk 30.11.1998 leg. H. Pieper (SAMA).

Diagnosis

Distinguished from all other species of the genus *Lestignathus* by presence of only 1 setiferous puncture on 3rd elytral interval. Further distinguished from *L. cursor* Erichson by much lesser size; from both, *L. foveatus* Sloane and *L. simsoni* Bates, by less cordate, anteriorly much

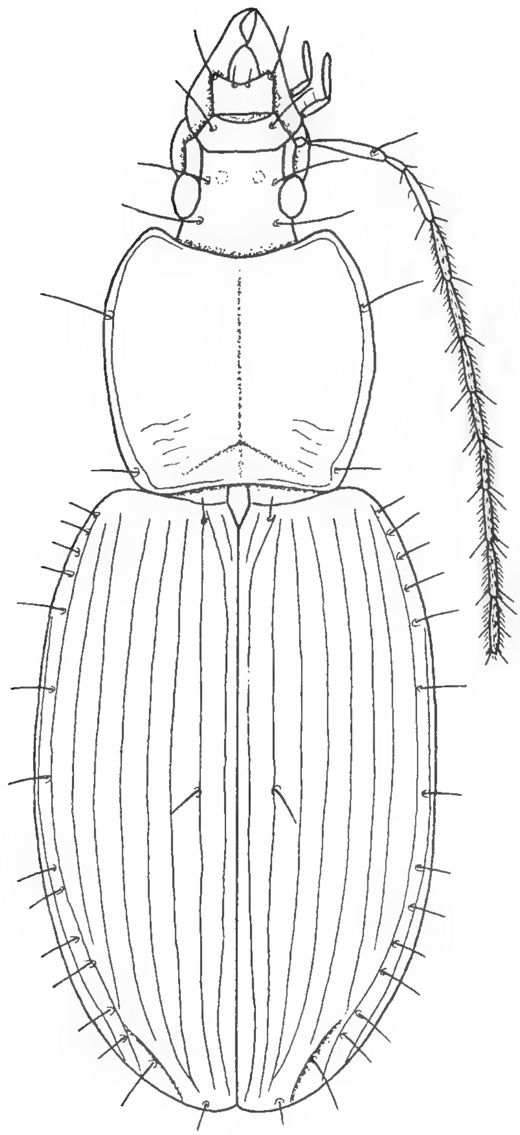

FIGURE 1. *Lestignathus pieperi* sp. nov. Habitus. Length: 7.55 mm.

narrower pronotum, almost completely depressed elytral intervals, and narrower head which is less than half as wide as pronotum; and from latter species also by slightly lesser size.

Description

Measurements. Length: 7.55 mm; width: 3.0 mm. Ratios: width/length of pronotum: 1.06; width base/apex of pronotum: 1.37; width pronotum/head: 2.08; length/width of elytra: 1.59; width elytra/pronotum: 1.52.

Colour. Piceous-black, pronotum and elytra with narrow reddish margins; labrum and mouthparts red, clypeus reddish-piceous, basal and apical antennomeres reddish, median antennomeres piceous, femora and tibiae in middle reddish-piceous, basally and apically lighter, tarsi light reddish. Lower surface black.

Head. Very small in comparison to prothorax. Eyes large though laterally little produced, with small orbits. Clypeus bisetose, anterior central part of clypeus membranous. Labrum medially deeply, symmetrically v-shaped, excised for about a third of its length, quadrisetose. Mentum with an indistinct, slightly triangular tooth, ligula bisetose, glossa and paraglossae of about equal length. Lacinia with elongate tooth at end, median border with dense fringe of stiff setae. Palpi rather slender and elongate, apical palpomeres thickened, both terminal palpomeres extremely sparsely pilose. Both mandibles bidentate, though lower tooth of right mandible more acute than that of left mandible, therefore apical excision in right mandible about quadrate, in left mandible more semicircular. Clypeofrontal suture very shallow, straight. Frons convex, near clypeal suture with shallow, rather irregularly shaped impression on either side. Both supraorbital pores very large. Frons impunctate, with distinct, isodiametric microreticulation. Antenna slender and elongate, surpassing anterior third of elytra, median antennomeres > 4 x as long as wide, two basal antennomeres glabrous, 3rd antennomere sparsely pilose, the following antennomeres densely pilose.

Prothorax. Slightly wider than long, laterally fairly convex, more than twice as wide as head, widest slightly in front of middle. Apex in middle deeply excised, anterior angles prominent, at apex rounded off. Lateral margin in basal half almost straight. Base distinctly concave in middle, basal angles widely rounded off. Apex and lateral borders with narrow though distinct margin, base in middle not margined. Median line distinct though shallow, almost complete. Anterior and posterior transverse impressions barely indicated. Basal impressions large, wide, with an elongate, linear impression in median part. Disk rather depressed, near basal angles widely explanate, rather even. Disk without any wrinkles or punctures, with distinct, more or less isodiametric microreticulation. Anterior marginal seta situated slightly behind anterior third, well in front of widest diameter, slightly removed from margin. Posterior marginal seta situated a short distance in front of basal angle, close to margin.

Elytra. Elongate-ovalish, widest about at

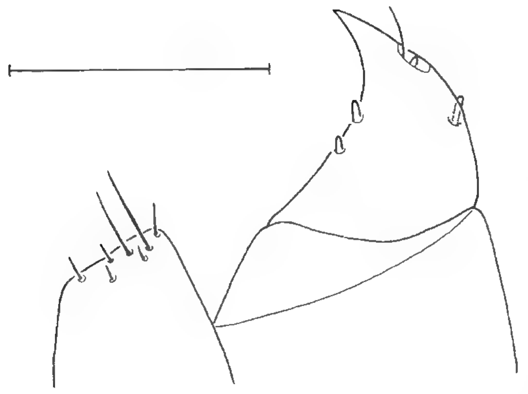

FIGURE 2. *Lestignathus pieperi* sp. nov. Female stylomere 2 and base of stylomere 1. Scale line: 0.25 mm.

middle, surface moderately convex, considerably wider than prothorax. Humeri barely projecting, basal and lateral margins meeting without any angle. Lateral margin evenly rounded to apex, slightly incurved at the very tip. Striation complete, striae well impressed, very faintly crenulate, intervals gently convex. Scutellar stria elongate, scutellar pore present. 3rd interval with a setiferous puncture in about middle, puncture attached to 2nd stria. Marginal series consisting of 13–14 large punctures that are more widely spaced in middle. Two additional punctures situated preapically and apically at 7th stria. Intervals impunctate, with highly superficial, transverse microreticulation, rather glossy. Wings reduced.

Lower surface. Impunctate. Metepisternum about as long as wide. Terminal abdominal sternite in female with 4 setae on either side.

Legs. Slender and elongate. Structure of male anterior tarsus unknown. Metatibia almost straight. Metatarsus very slender. 5th tarsomeres of all legs slender, lower surface setulose.

Male genitalia. Unknown.

Female genitalia (Fig. 2). Both stylomeres markedly depressed, foliaceous. Stylomere 2 short and wide, triangular, with short, acute apex, laterally with 2 very short latero-ventral ensiform setae, mediodorsally with a moderately short dorso-medial ensiform seta, on median rim near apex with a nematiform seta originating in a large groove. In middle of the groove with a small tubercle. Apex of stylomere 1 without any setae. Lateral plate conspicuously triangular at apex, with a 2–3 elongate and some very short nematiform setae at apical rim.

Variation. Unknown.

Distribution. Mt Field, southwestern Tasmania. Known only from type locality.

Collecting circumstances. Collected on the ground in temperate rain forest. The holotype was captured together with *Lestignathus cursor* Erichson.

Etymology. The name is a patronym in honour of the collector Dr Harald Pieper.

Relationships

The sparsely setulose 3rd antennomere and the presence of both marginal pores on the pronotum place this species in the genus *Lestignathus* Erichson, although externally it resembles species of the related genus *Lacordairia* Castelnau.

Because the male genitalia of this species are not yet known and two of the three other species of *Lestignathus* are apparently very rare, nothing can be said about relationships of this species, which is unique within the genus by the presence of a single elytral puncture only. Certainly, all species of the genus differ remarkably in certain external characters.

KEY TO THE SPECIES OF *LESTIGNATHUS* ERICHSON

1. — Size larger, body length >12.5 mm; elytra with 2 non-foveate punctures, at apex not deeply sinuate .... *cursor* Erichson
   — Size smaller, body length <10 mm; elytra either with foveate punctures, or with 1 puncture only, or at apex deeply sinuate 2
2. — Each elytron with 3–4 foveate punctures .. .. *foveatus* Sloane
   — Each elytron with at most 2 non-foveate punctures 3
3. — Size larger, body length >9 mm; each elytron with 2 setiferous punctures, apex of elytra deeply sinuate .... *simsoni* Bates
   — Size smaller, body length c. 7.5 mm; each elytron with 1 setiferous puncture, apex of elytra barely sinuate ...... *pieperi* sp. nov.

***Mecyclothorax punctipennis* (Macleay)**

Moore 1984: 162; Moore *et al.* 1987: 149.

The material collected recently by H. Pieper in Tasmania includes a male specimen of *Mecyclothorax punctipennis* (Macleay) besides specimens of the well known *M. ambiguus* (Erichson). The identity of *M. punctipennis* has been confirmed by dissection of the male genitalia and by comparsion with genitalia of the Tasmanian *M. ambiguus*, moreover by comparison with the figures in Moore (1984). Data for this specimen are: TAS, Rocky Cape NP, 22.11.1998, leg. H. Pieper.

This is the first Tasmanian record of this species which is common and widespread on the mainland (Moore *et al.* 1987).

Acknowledgments

My sincere thanks are due to Dr H. Pieper (Kiel) for kindly submitting his interesting material for identification, and to Dr E. Matthews (Adelaide) for the kind loan of types and material for comparison.

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SIX NEW SPECIES OF *NIRRIDESSUS* WATTS AND HUMPHREYS AND *TJIRTUDESSUS* WATTS AND HUMPHREYS (COLEOPTERA:DYTISCIDAE) FROM UNDERGROUND WATERS IN AUSTRALIA.

BY C.H.S. WATTS AND W.F. HUMPHREYS

Summary

WATTS, C.H.S. AND HUMPHREYS, W.F. (2000). Six new species (*Nirridessus bigbellensis, N. cueensis, N. hinkleri, N. morgani, Tjirtudessus hahni* and *T. magnificus*) of stygobiontic beetles of the family Dytiscidae, subfamily Hydroporinae, tribe Bidessini, from relatively shallow, calcrete aquifiers in Western Australia, are described and figured, The species are members of a diverse , recently discovered, relictual stygofauna, predominantly of Crustacea and Oligochaeta, inhabiting calcretes lying along palaeodrainage channels. The two genera occur in palaeochannel deposits on either side of the divide beteween the inland and Indian Ocean drainages. Each calcrete area contains a distinct assemblage of beetles and the fauna occurs in both fresh and saline groundwater. The physicochemical properties of the groundwater, and the palaeogeography and hydrology of the region are discussed in some detail.

SIX NEW SPECIES OF *NIRRIDESSUS* WATTS AND HUMPHREYS AND *TJIRTUDESSUS* WATTS AND HUMPHREYS (COLEOPTERA: DYTISCIDAE) FROM UNDERGROUND WATERS IN AUSTRALIA

C. H. S. WATTS AND W. F. HUMPHREYS

WATTS, C. H. S. and HUMPHREYS, W. F. 2000. Six new species of *Nirridessus* Watts and Humphreys and *Tjirtudessus* Watts and Humphreys (Coleoptera: Dytiscidae) from underground waters in Australia. *Records of the South Australian Museum* **33**(2): 127–144.

Six new species (*Nirridessus bigbellensis, N. cueensis, N. hinkleri, N. morgani, Tjirtudessus hahni* and *T. magnificus*) of stygobiontic beetles of the family Dytiscidae, subfamily Hydroporinae, tribe Bidessini, from relatively shallow, calcrete aquifers in Western Australia, are described and figured. The species are members of a diverse, recently discovered, relictual stygofauna, predominantly of Crustacea and Oligochaeta, inhabiting calcretes lying along palaeodrainage channels. The two genera occur in palaeochannel deposits on either side of the divide between the inland and Indian Ocean drainages. Each calcrete area contains a distinct assemblage of beetles and the fauna occurs in both fresh and saline groundwater. The physico-chemical properties of the groundwater, and the palaeogeography and hydrology of the region are discussed in some detail.

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Stygobiotic water beetles have been reported from a number of widely scattered localities around the world (Spangler 1986) but it was not until 1999 that they were first reported from Australia (Watts and Humphreys 1999). These belonged to the Dytiscidae and were discovered living in relatively shallow calcrete aquifers in the Lake Way/Lake Carey palaeodrainage system of Western Australia. Five species in three genera in the tribe Bidessini were involved.

These groundwater calcretes are restricted to the arid parts of Australia (Fig. 40) where the potential evaporation exceeds rainfall by more than an order of magnitude (detailed in Humphreys 1999; Watts and Humphreys 1999).

In May 1999 one of us (W.F.H.) spent some time investigating other areas of inland palaeodrainage in Western Australia with groundwater calcretes and discovered additional stygofaunas which included dytiscids.

In this paper we describe the six species of Dytiscidae collected and record the existence of a further two, all belonging to two of the original genera: *Tjirtudessus* and *Nirridessus*. We also give details of the physico-chemical properties of the water in the aquifers and the palaeogeography and hydrology of the region.

Methods

About 120 sites were sampled, comprising pastoral wells and boreholes constructed for water abstraction, groundwater investigation and mineral exploration in a number of fractured rock, alluvial and groundwater calcrete aquifers from the central Yilgarn Craton of Western Australia (Fig. 38). The beetles and associated fauna were taken by plankton nets hauled through the water column of the bores and wells, or sometimes from baited traps.

Physico-chemical parameters in the water were determined either *in situ*, or in a sample taken near the surface using a bailer, using electronic instruments—pH using a WTW pH 320 meter with a SenTix 97T pH combined electrode with integrated temperature sensor and redox probe, and dissolved oxygen using a WTW Oxi 320 meter and a CellOx 325 oxygen sensor (Wissenschaftlich-Technisch Werkstatten GmbH, Weilheim, Germany). Conductivity was measured with a TPS Model LC 84 conductivity meter (TPI Electronics, Springwood, Queensland, Australia). All were calibrated as specified using the recommended standards. In some samples the salinity was determined using a hand refractometer (Atago S-10e).

Abbreviations used

BES Prefix for field numbers, WAM Biospeleology.

OB Observation bore.

PAT Prefix, observation bore number, Austin Downs Borefield, Big Bell Mine.

SB Prefix, piezometer number in Hinkler Well calcrete to the west of Lake Way.

TPB Prefix, piezometer number in Hinkler Well calcrete to the west of Lake Way.

SAMA South Australian Museum, Adelaide.

WAM Western Australian Museum, Perth.

Systematics

Key To Australian Species Of Stygobionic Bidessini

1. — Body length <1.2 mm, dorsal surface strongly reticulate, legs stout, without swimming-hairs on fore and midlegs .... *Kintingka kurutjutu* Watts & Humphreys

— Body length >1.2 mm, dorsal surface with weak to moderate reticulation, legs normal, all legs with swimming hairs 2

2. — Pronotum usually wider than elytra (Fig. 1); third and fourth (apical) segments of labial palpi subequal in length (Figs 23–25); setae on hind edge of mesofemur not greatly different in robustness from those on mesotrochanter (Figs 10, 19, 20). Length > 3.0 mm .... (*Tjirtudessus*) 9

— Pronotum same width or narrower than elytra (Figs 3–6); third segments of labial palpi half to two thirds length of apical (Figs 26–32); setae on hind edge of mesofemur near base much more robust than those on mesotrochanter or elsewhere on femur (Figs 7–9). Length 1.0–3.2 mm .... (*Nirridessus*) 3

3. — Pronotal plicae well marked 4

— Pronotal plicae difficult to trace 5

4. — Length of metatarsal segments 1 & 2 > segments 3 & 4; eye remnant present; parameres with long apical lobe .... *N. pulpa* Watts & Humphreys

— Length of metatarsal segments 1 & 2 = < segments 3 & 4; without eye remnant; parameres with small apical lobe (Fig. 33) .... *N. morgani* sp. nov.

5. — Length => 3.0 mm; eye remnant present (Fig. 5); group of six spines close to base of mesofemur on hind edge (Fig. 11) .... *N. bigbellensis* sp.nov.

— Length =< 2.5 mm; with or without eye remnant; spines on mesofemur spread out along hind edge or, if restricted to base, four or fewer (Figs 8, 9, 13, 15) 6

6. — Pro- and mesotarsi broad (Fig. 4); segments two and three of antennae similar in shape; apical lobe of paramere overlies part of rest of paramere (Fig. 34) .... *N. cueensis* sp.nov.

— Pro- and mesotarsi only weakly expanded (Fig. 3); segments two and three of antennae different in shape, second broad and rounded, third narrow and triangular; apical lobe of paramere well separated from rest of paramere (Fig. 35) 7

7. — Elytron without subsutural row of punctures; metatrochanters bluntly pointed (Fig. 14); length approximately 1.5 mm; median lobe of aedeagus truncated (Fig. 35) .... *N. hinkleri* sp.nov.

— Elytron with row of large subsutural punctures; metatrochanters rounded; length up to 2.5mm; median lobe of aedeagus pointed 8

8. — Length 2.2–2.3 mm; with eye remnant...... .. *N. windarraensis* Watts & Humphreys

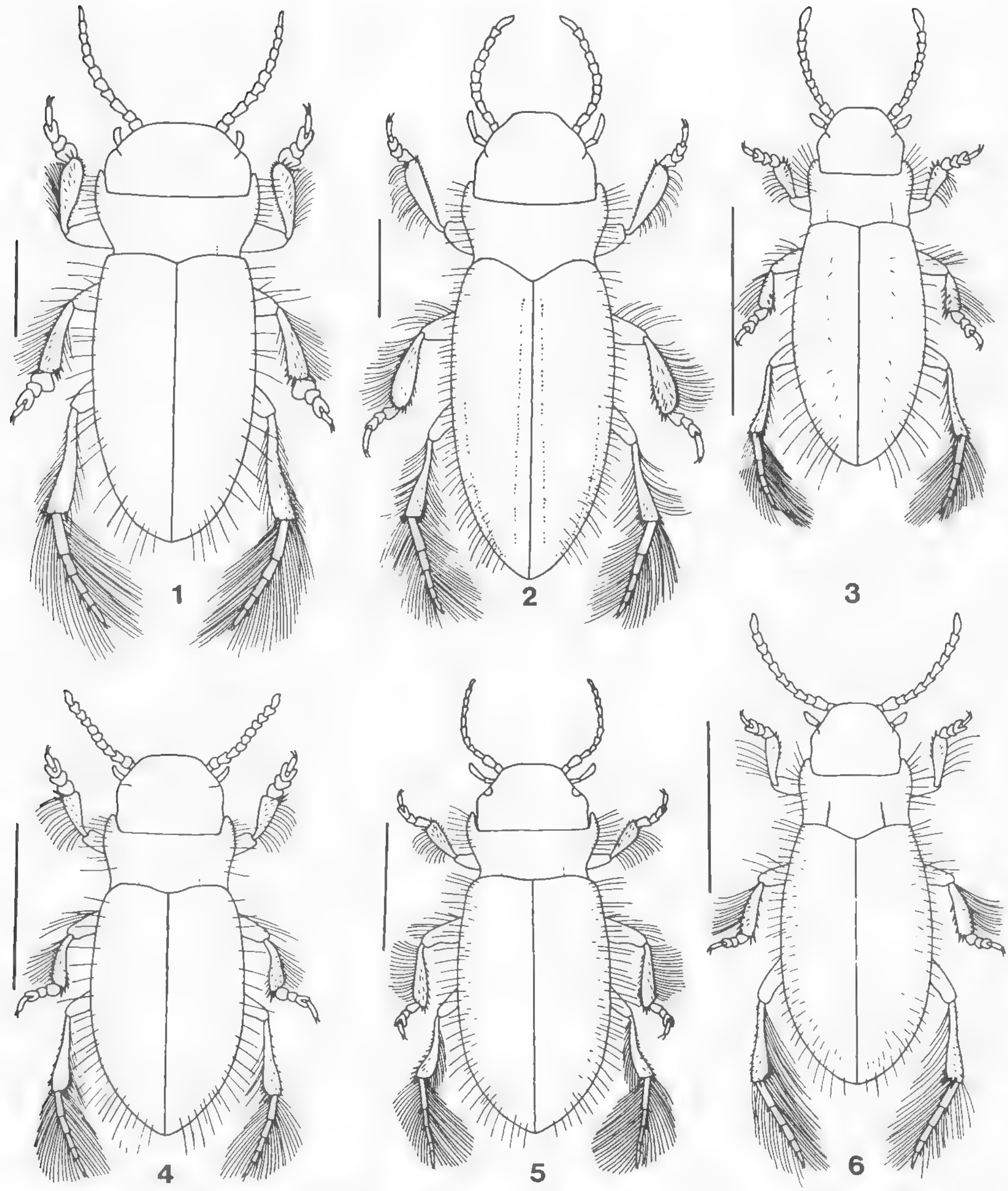
— Length 1.3–1.5 mm; without eye remnant .... *N. lapostaae* Watts & Humphreys

9. — Pro- and mesotarsi strongly expanded (Fig. 1); apical five segments of antennae noticeably thinner than others (Fig. 1) ... . *T. magnificus* sp. nov.

— Pro- and mesotarsi only moderately expanded (Fig. 2); apical five segments of antennae not narrower than others (Fig. 2) 10

10. — Length > 4.0mm; median lobe of aedeagus twisted, tip knobbed (Fig. 37); without eye remnant; pronotum at its base a little narrower than elytra (Fig. 2) .... *T. hahni* sp. nov.

— Length < 4.0mm; median lobe of aedeagus not twisted, tip pointed; with small eye remnant; pronotum at its base wider than elytra .... *T. eberhardi* Watts & Humphreys



FIGURES 1–6. **1**, Dorsal view of *Tjirtudessus magnificus*; **2**, ditto *T. hahni*; **3**, ditto *Nirridessus hinkleri*; **4**, ditto *N. cueensis*; **5**, ditto *N. bigbellensis*; **6**, ditto *N. morgani*. Scale bar = 1mm.

Tjirtudessus Watts & Humphreys, 1999

Tjirtudessus magnificus sp. nov.

Types

Holotype: m. 'BES 7040, Old Cue water supply bore, 27°16'10"S, 117°59'23" E, 12/5/99, coll W. F. Humphreys & H. J. Hahn', in spirit, WAM, registration number 26840.

Paratype: f. BES 7066, same data as for holotype except 13/5/99, SAMA.

Description (number examined, 2) Figs 1, 19, 20, 25, 36.

Habitus: Length 4.7–4.8 mm.; relatively flat, strongly constricted at junction of pronotum/ elytra; uniformly light testaceous; hindwing vestigial, about half length of elytron (Fig 1).

Head: Large, nearly as wide as elytra; smooth, reticulation very fine, punctures sparse, weak; subparallel in posterior half; sides with dark suture in middle near anterior edge. Antenna relatively stout, basal two segments cylindrical, third segment longer and narrower at base, next three subequal, next four progressively thinner, apical segment a bit longer and much narrower than penultimate, each segment with some very small setae on inside apically (Fig. 1). Maxillary palpus thin, elongate, apical segment large, a little shorter than segments one to three combined, three long setae on outer side and some sensillae towards tip, tip truncated. Labial palpus moderate, apical two segments subequal, tip weakly bifid, penultimate segment with small papilla near tip bearing two setae (Fig. 25).

Pronotum: Very broad, wider than elytra (Fig. 1); anterolateral angles projecting strongly forward; base quite strongly narrowed, posterolateral angles acute; smooth, with sparse, very weak punctures and a row of stronger punctures along front margin; basal plicae weak, reaching to about half way along pronotum, slightly excavated inwards; with row of long setae laterally, denser towards front.

Elytra: Not fused, lacking inner ridges; elongate, widest behind middle, smooth, quite densely and evenly covered with very small punctures, row of widely spaced larger punctures close to inner edge; lacking setiferous micropunctures; row of long setae near lateral edge, a few additional larger punctures with long setae, more frequent towards sides. Epipleuron broad in anterior fifth, then rapidly narrowing to be virtually absent over rest of elytron.

Ventral surface: Prothoracic process relatively broad, strongly narrowed between coxae, not reaching mesothorax, apical half spatulate, strongly arched in lateral view with highest point (viewed ventrally) between coxae. Mesocoxae in contact at midline. Metathorax sharply triangular in front in midline, wings very narrow, broadly rounded in midline behind. Metacoxal plates large, metacoxal lines short, weak, widely spaced, reaching to about halfway to metasternum, diverging in anterior two-thirds; moderately covered with small setae-bearing punctures; closely adpressed to first abdominal ventrite. First and second ventrites fused, sutural lines distinct, ventrites three to five mobile, moderately covered with small seta-bearing punctures, ventrites three and four with a long central seta or bunch of long setae.

Legs: Protibia relatively narrow, inner edge straight, outer edge bowed, widest past middle where it is about three times its basal width; protarsi greatly expanded, first segment very broadly oval, second segment broad about one third length of first, third segment as long as first but much narrower and very deeply bifid, fourth segment very small and hidden within lobes of third segment, apical segment narrow, cylindrical, about length of third, segments one to three with very dense covering of adhesive setae; claws short and simple. Mesotrochanter rounded with row of setae on inner edge; mesofemur with row of 10–12 relatively weak setae along hind edge in basal half (Fig.19); mesotarsi similar to protarsi. Metatrochanter weakly pointed (Fig. 20); metafemur elongate, lacking spines; metatibia strongly curved, widening towards apex; metatarsi elongate, basal segment longest, apical segment a little longer than fourth, segments one and two in combination about as long as others; claws weak.

Male: Antennae a little stouter; pro- and mesotarsi a little stouter. Median lobe of aedeagus narrow, narrowing rapidly in apical quarter; paramere broad, apical segment with pronounced, narrow, apical lobe (Fig. 36).

Etymology

The species is named in reference to its appearance.

Remarks

A very large broad flat *Tjirtudessus* readily recognised by the large round first segment of the pro- and mesotarsi of both sexes, and the distinctive antennae with the apical segments noticeably narrower than the middle segments.

Tjirtudessus hahni sp. nov.

Types

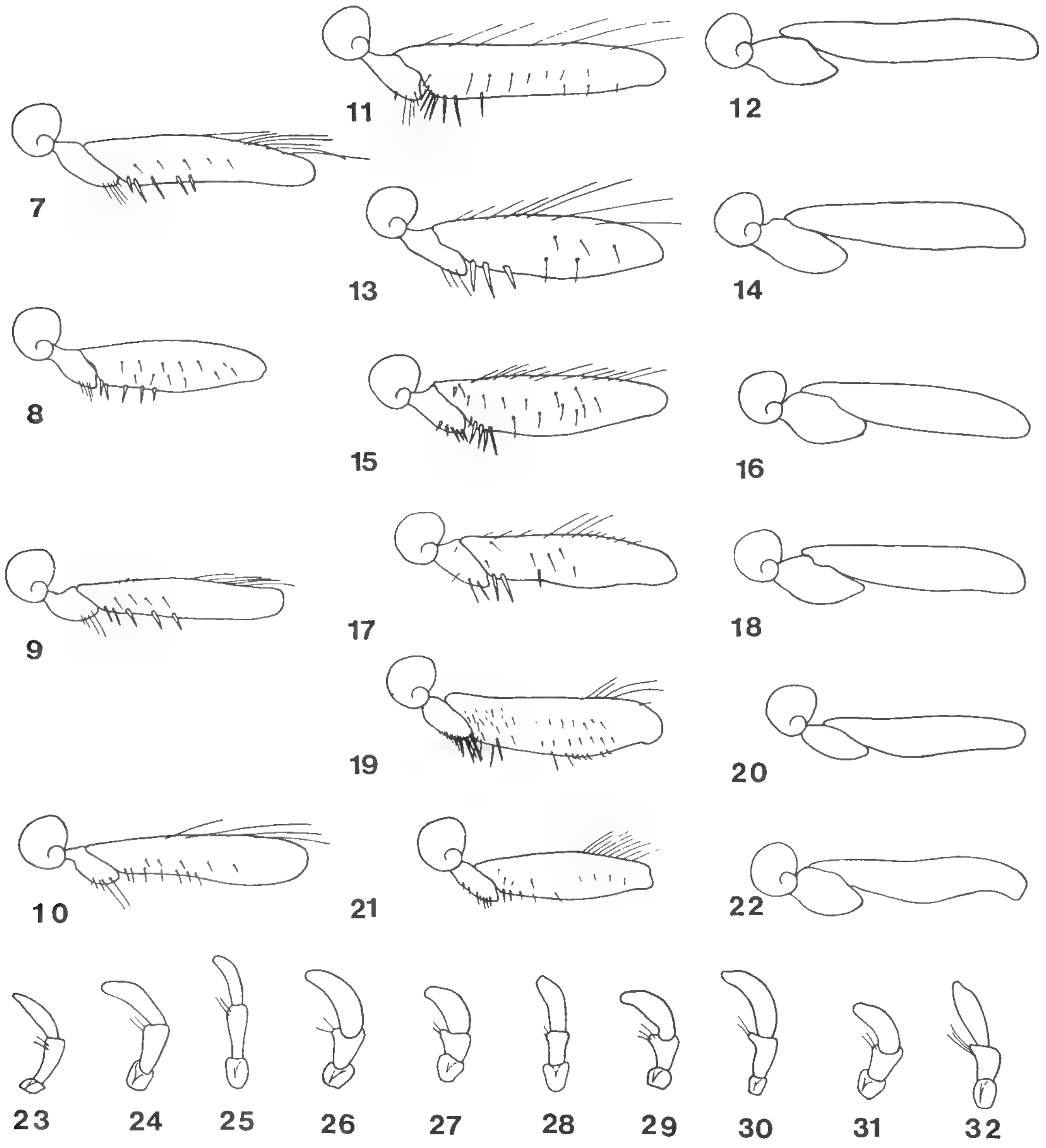
Holotype: m. 'BES 7197, mineral exploration bore, 26°41'16"S, 120°17'52"E, 21/5/99, coll. W. F. Humphreys & H. J. Hahn', slide mounted, WAM, registration number 26887.

Paratypes: 4; same data as holotype, most incomplete, 2 slide mounted, SAMA, 2 in spirit, WAM, registration numbers 26841, 26842.

Description (number examined, 5) Figs 2, 21, 22, 24, 37.

Habitus: Length 4.8 mm.; relatively flat, strongly constricted at junction of pronotum/elytra; uniformly light testaceous; hindwing vestigial, about one-third length of elytron (Fig. 2).

Head: Large, smooth, reticulation very fine, punctures sparse, weak; subparallel in posterior



FIGURES 7–32. **7**, Ventral view of mesotrochanter and mesofemur of *Nirridessus pulpa*; **8**, ditto *N. windarraensis*; **9**, ditto *N. lapostaae*; **10**, ditto *Tjirtudessus eberhardi*; **11–12**, ventral views of mesotrochanter and mesofemur and metatrochanter and metafemur of *N. bigbellensis*; **13–14,** ditto *N. hinkleri*; **15–16**, ditto *N. cueensis*; **17–18**, ditto *N. morgani*; **19–20** ditto *T. magnificus*; **21–22**, ditto *T. hahni*; **23,** labial palpus of *T. eberhardi*; **24**, ditto *T. hahni*; **25**, ditto *T. magnificus*; **26**, ditto *N. bigbellensis*; **27**, ditto *N. hinkleri*; **28**, ditto *N. morgani*; **29**, ditto *N. cueensis*; **30**, ditto *N. windarraensis*; **31**, ditto *N. lapostaae*; **32,** ditto *N. pulpa*.

half; sides with dark suture in middle near anterior edge. Antenna stout, basal two segments largest, next six segments narrower at base, subequal, segment six the widest, apical segment twice as long as penultimate (Fig. 2); each segment with some very small setae on inside apically. Maxillary palpus relatively thin, elongate; apical segment largest, some sensillae towards tip, tip weakly bifid. Labial palpus not particularly thin; apical two segments subequal; tip weakly bifid; penultimate segment with two setae near apex arising from slight bulge (Fig. 24).

Pronotum: Broad, a little narrower than elytra (Fig. 2); anterolateral angles projecting strongly forward; base quite strongly narrowed; posterolateral angles acute; smooth, punctures sparse, very small, a row of stronger punctures along front margin; basal plicae short, very weak, only visible in some lights; row of long setae laterally, denser towards front.

Elytra: Not fused; lacking inner ridges; elongate, widest behind middle. Elytron smooth, quite densely and evenly covered with small punctures each with a small seta, row of widely spaced larger punctures close to inner edge; some setiferous micropunctures at base, near suture and near apex; row of long setae near lateral edge, a few additional long setae, more frequent towards sides. Epipleuron broad in anterior fifth, then rapidly narrowing to be virtually absent over rest of elytron.

Ventral surface: Prothoracic process relatively broad, strongly narrowed between coxae, not reaching mesothorax, apical half spatulate, tip rounded, strongly arched in lateral view with highest point (viewed ventrally) between coxae. Mesocoxae meet. Metathorax sharply triangular in front in midline, wings very narrow, broadly rounded in midline behind. Metacoxal plates large; metacoxal lines short, weak, widely spaced, almost obsolete; punctures very sparse, very weak; closely adpressed to first abdominal ventrite. First and second ventrites fused, sutural line virtually obliterated, ventrites three to five mobile, moderately covered with small seta-bearing punctures, ventrites three and four with a long central seta or bunch of long setae.

Legs: Protibia moderately broad, inner edge straight, outer edge bowed, widest past middle where it is about three times its basal width; protarsi weakly expanded, second segment about half length of first, third segment equal in length to first, fourth segment very small and hidden within deeply lobed third segment, apical segment long, thin, segments one to three with dense covering of adhesive setae, claws relatively strong, simple. Mesotrochanter parallel-sided broadly triangular at apex with a few setae on inner edge, mesofemur with a row of five to six relatively weak setae along hind edge in basal half (Fig. 21); mesotarsi more elongate than protarsi. Metatrochanter curved on outer edge straight on inner edge (Fig. 22), metafemur elongate, sinuate (Fig. 22), metatibia weakly curved, widening towards apex; metatarsi elongate, basal segment longest, apical segment a little longer than fourth, segments one and two in combination about as long as others; claws weak.

Male: Antennae and tarsi as in female. Median lobe of aedeagus narrow, twisted slightly, knobbed at apex; paramere broad, two-segmented, apical segment with pronounced, narrow, apical lobe (Fig. 37).

Etymology

This species is named after Hans Jurgen Hahn who assisted with describing the physicochemical environment occupied by the stygofauna. The type locality is an excellent example of this kind of habitat.

Remarks

T. hahni resembles *T. magnificus* in its large size and broad body but differs in its much less expanded pro- and mesotarsi and in its more normal antennae which have segments 5–10 subequal in size. It can be separated from both *T. magnificus* and *T. eberhardi* by the median lobe of the aedeagus which is noticeably twisted and has a rounded knob at the tip and by its pronotum which, unlike in those species, is a little narrower than the elytra.

Nirridessus Watts & Humphreys, 1999.

Nirridessus hinkleri sp. nov.

Types

Holotype: m. 'BES 7134, SB 32/1, 26°52'31"S, 120°12'05"E, 17/5/99, coll. W. F. Humphreys & H. J. Hahn', slide mounted, WAM, registration number 26843.

Paratypes: 58, same data as holotype, 29 WAM, registration number 26844, 28 SAMA; 3, 'BES 7130, TPB25/4, 26°52'50"S, 120°09'44"E, 17/5/99', 1 WAM, registration number 26845, 2 SAMA; 3, 'BES 7218, 26°51'37"S, 120°18'05"E, 22/5/99', 2 WAM, registration numbers 26846, 26847, 1 SAMA; 34, 'BES 7137, SB32/1, 26°52'31"S 120°18'05"E', 12 WAM, registration number 26848, 15 SAMA; 3, 'BES 7136, 26°52'31"S 120°12'05"E', WAM, registration numbers 26849, 26850, 26851; 1, 'BES 7166, 26°41'14"S 120°18'09"E', WAM, registration number 26852; 2, BES 7228, 1 WAM, registration number 26853, 1 SAMA. All collected by W. F. Humphreys & H. J. Hahn.

Additional specimen

The following partial specimen probably belongs to this species. BES 7222 Hinkler calcrete east, 26°51'36"S, 120°18'05"E, 22/5/99, coll. W. F. Humphreys & H. J. Hahn. WAM registration number 26854.

Description (number examined, 106) Figs 3, 13, 14, 27, 35.

Habitus: Length 1.4–1.8 mm.; relatively flat, elongate, pronotum narrowing at base; uniformly very light testaceous; hindwing vestigial, reduced to about one half length of elytron.

Head: Broad, parallel sided in basal half, rapidly narrowing forward of area where eye would be; a short dark suture at each side in middle at edge; reticulation moderate; punctures sparse, weak, row of setiferous punctures running backwards from above antennal base. Antenna moderately stout (Fig. 3), basal segment parallel sided, second segment rounded, third much narrower than second, fourth much shorter, then approximately the same size until penultimate, apical segment thinner and about twice as long as penultimate, a few small setae near apex of each segment. Tip of last segment of maxillary palpus very weakly bifid, a few small setae towards tip, penultimate segment much shorter than apical, with small papilla bearing two setae near apex (Fig. 27).

Pronotum: A little narrower than elytra (Fig. 3), broad in front, narrowing behind, strongly extended forward at anterolateral angles, posterolateral angles acute; punctures very sparse, weak, a few larger punctures towards front edge; moderately reticulate; basal plicae weak, straight, reaching about half way along pronotum; row of long, thin setae in front half at edges and on forward extensions.

Elytra: Not fused but tightly locked; lacking inner ridges; widest in middle; punctures very fine, very sparse, each with a small seta, a few punctures with longer setae; moderately reticulate; moderately covered with micropunctures at base, near suture and apex; sides of elytra quite strongly vertical, with row of long thin setae at edge, denser towards front. Epipleuron present in anterior quarter, absent in apical half.

Ventral surface: Pronotal process arched in lateral view, highest point (viewed ventrally) between coxae, apical half roughly parallel-sided, bluntly pointed, narrowing between coxae, not reaching metathorax. Mesocoxae in contact in midline. Metathorax with a few very small punctures; quite sharply triangular in midline in front; wings very narrow, subobsolete; narrowing to a broad point behind in midline. Metacoxal lines, well separated, weakly diverging, reaching to about halfway to mesosternum; sparsely punctate; adpressed to first abdominal ventrite. Metacoxal plates and first and second ventrites fused but sutures evident, other ventrites free, sternites three and four with central group of setae, otherwise virtually without setae; virtually impunctate.

Legs: Protibia relatively thin, about four times as broad at apex than at base; protarsi weakly expanded, second segment about a quarter the length of first, fourth segment very small, hidden within deeply bilobed third segment, adhesive setae sparse, weak; claws weak. Mesotrochanter relatively large, rounded with a few setae on inner edge; mesofemur with three to four strong spines on hind edge restricted to basal half but not all grouped near base (Fig. 13); mesotarsi less strongly expanded than protarsi. Metatrochanter large, outer edge curved, inner edge straight, weakly pointed, well separated from femur at apex (Fig. 14); metafemur relatively narrow, anterior edge weakly sinuate, impunctate, without spines; metatibia strongly curved, thickening apically; metatarsal segments elongate, progressively smaller towards apical segment which is a little longer than penultimate, combined length of basal two segments approximately equal to other three; claws weak, outer one slightly smaller than inner.

Male: Appendages and legs as for female. Median lobe of aedeagus moderately broad, concave above, tip broadly rounded with small central point; parameres moderately broad, two segmented, apical segment with pronounced narrow apical portion (Fig. 35).

Etymology

The name pertains to the Hinkler Well Catchment in which the classic study of the hydrogeochemistry of ground water calcretes was undertaken (Mann and Deutscher 1978).

Remarks

This is a small species with a distinctive aedeagus. The pointed rather than rounded metatrochanters and acute rather than rectangular posterolateral angles to the pronotum, will separate it from the similar sized *N. lapostaae*.

Nirridessus cueensis sp. nov.

Types

Holotype: m. 'BES 7040, Old Cue water supply bores, 27°16'11"S, 117°59'23"E, 12/5/99, coll W. F. Humphreys & H. J. Hahn', slide mounted, WAM, registration number 26856.

Paratypes: 6, same data as holotype, 2 SAMA, 4 WAM, registration numbers 26857, 26858, 26859, 26860; 8, same data as holotype except for, 'BES 7067, 13/5/99', 4, SAMA 4, WAM, registration numbers 26861, 26862, 26863, 26864; 2, same data as holotype except for 'BES 7038', WAM, registration numbers 26865, 26866.

Description (number examined, 18) Figs 4, 15, 16, 29, 34.

Habitus: Length 2.1–2.4 mm.; relatively flat, elongate, pronotum a little narrower than elytra, constricted at base; uniformly very light testaceous; hindwing vestigial, reduced to about one half length of elytron.

Head: Broad, parallel sided in basal half, rapidly narrowing forward of area where eye would be; a short dark suture at each side in middle at edge; reticulation very weak; punctures sparse, weak, row of setiferous punctures running backwards from above antenna base. Antenna stout, robust, basal segment cylindrical, second more elongate, third smaller narrowing to base, then progressively widening until penultimate, apical segment thinner and slightly longer, a few small setae near apex of each segment. Last segment of maxillary palpus relatively broad, tip weakly bifid, a few small setae towards tip. Penultimate segment of labial palpus with strong cone-like projection near apex bearing two setae, approximately two thirds length of apical (Fig. 29).

Pronotum: Same width or a bit narrower than elytra, broad in front, narrowing quite markedly behind, strongly extended forward at anterolateral angles, posterolateral angles rectangular; punctures sparse, weak; weakly reticulate; two fine, basal plicae weakly impressed, straight, reaching about a half way along pronotum; row of long, thin setae in front half at edges and on forward extensions.

Elytra: Not fused but tightly locked, lacking inner ridges; widest in middle; punctures very fine, sparse, each with a small seta, a few punctures with longer setae; a few micropunctures near apex; sides of elytra quite strongly vertical; with row of long thin setae at edge, denser towards front. Epipleuron broad in front, narrowing quite rapidly to level of first sternite, then thin to apex, difficult to differentiate from disc.

Ventral surface: Pronotal process arched in lateral view, highest point (viewed ventrally) between coxae, apical half broadly spatulate, narrowing between coxae, not reaching metathorax. Mesocoxae in contact in midline. Metathorax with a few very small punctures; quite sharply triangular in midline in front; wings very narrow, subobsolete; rounded behind. Metacoxal plates with weakly raised central portion; metacoxal lines weak, well separated, diverging in anterior third, reaching to about halfway to mesosternum; sparsely punctate; adpressed to first abdominal ventrite. Metacoxal plates and first and second ventrites fused but sutures evident, other ventrites free, ventrites three and four with central group of setae, otherwise virtually without setae; virtually impunctate.

Legs: Protibia about three times as broad at apex than at base; protarsi moderately expanded, second segment half length of first, third segment deeply bilobed, a little longer than first, fourth segment very small and hidden within bilobed third segment, adhesive setae moderately dense; claws moderate. Mesotrochanter rounded at tip with some setae on inner edge (Fig. 15); mesofemur with three to five strong spines on hind edge grouped together near base (Fig.15); mesotarsi similar to protarsi. Metatrochanter large, outer edge rounded, inner edge straight, weakly separated from femur at apex (Fig.16); metafemur relatively narrow, anterior edge weakly sinuate, impunctate, without spines; metatibia strongly curved, thickening apically; metatarsal segments elongate, progressively smaller towards apical segment which is a little longer than penultimate, combined length of basal two segments approximately equal to other three; claws weak, outer one slightly smaller than other.

Male: Appendages and legs as above. Median lobe of aedeagus moderately broad, concave above, narrowing rapidly close to tip, small brush of setae dorsally near tip; parameres moderately broad, apical segment with pronounced narrow apical portion which partly overlaps basal portion (Fig. 34).

Etymology

This species is named after the type locality.

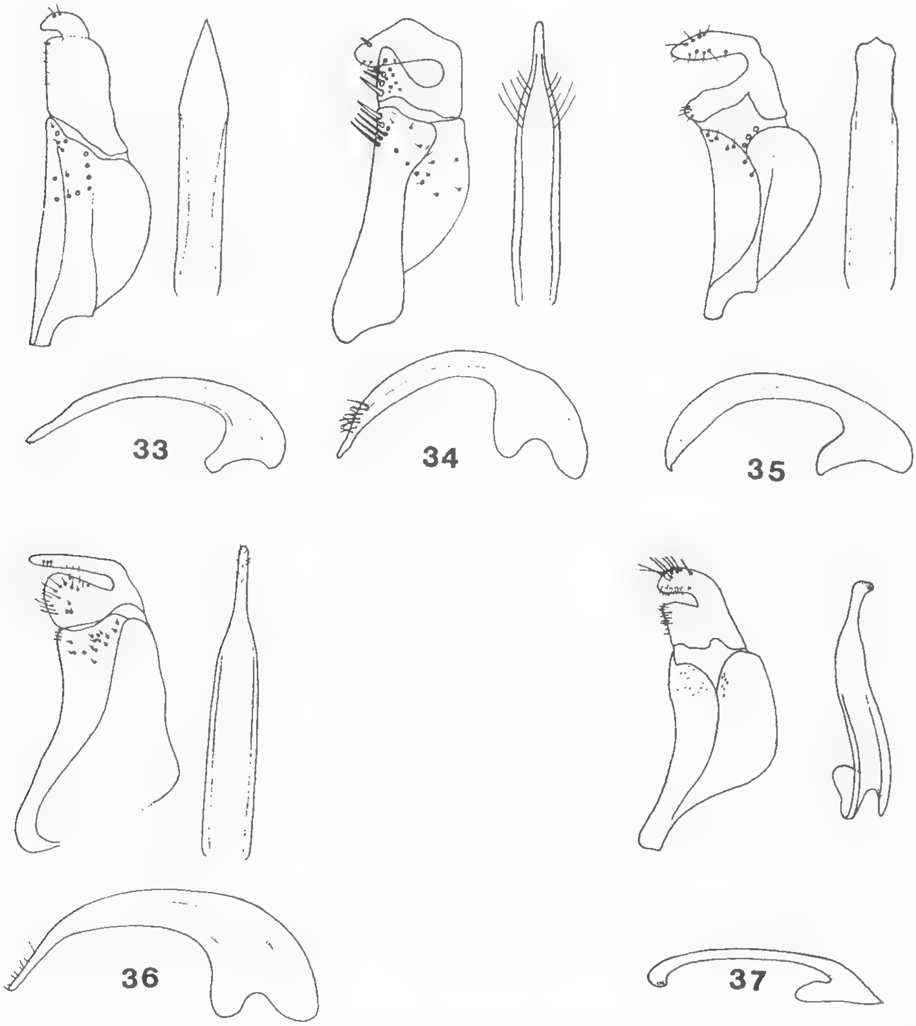
Remarks

Nirridessus cueensis seems close to *N. lapostaae* but is larger, its pro- and mesotarsi are much broader and its metatrochanters are not as rounded. The spines/strong setae on the hind edge of the mesofemur are grouped together near the base whereas in *N. lapostaae* they are more spread out along the basal half of the femur. The aedeagus differs from most *Nirridessus* by having a group of setae near the apex. The parameres are unique in *Nirridessus* in having the apical lobe overlapping part of the rest of the paramere and with strong spines on the inner edge (Fig. 34).

Nirridessus morgani sp. nov.

Types

Holotype: m. 'BES 7192, Sample 2 Site 284,



FIGURES 33–37. **33,** Paramere, dorsal view of central lobe and lateral view of central lobe of aedeagus of *Nirridessus morgani*; **34,** ditto *N. cueensis*; **35,** ditto *N. hinkleri*; **36,** ditto, *Tjirtudessus magnificus*; **37,** ditto *T. hahni*.

mineral exploration bore, 26°41'15"S, 120°21'10"E; 21/5/99, coll W. F. Humphreys & H. J. Hahn', in spirit, WAM, registration number 26867.

Paratypes: 6, as for holotype, 4 SAMA, 2 WAM, registration numbers 26868, 26869; 5, 'BES 7171, Site 262, mineral exploration bore, Lake Way, 26°68'74"S 120°35'31"E, 19/5/99', 1 SAMA, 4 WAM, registration numbers 26870, 26871, 26872, 26873.

Description (number examined, 10) Figs 6, 17, 18, 28, 33.

Habitus: Length 2.1–2.2 mm; relatively flat but deep bodied, elongate, pronotum weakly narrowing at base; uniformly very light testaceous; hindwing vestigial, reduced to about one half length of elytron.

Head: Relatively narrow, parallel sided in basal half, rapidly narrowing forward of area where eye would be; a short dark suture at each side in middle at edge; very weak reticulation; punctures sparse, weak, row of setiferous punctures running backwards from above antenna base; weakly reticulate. Antenna relatively stout, basal two segments broad, third narrower, fourth similar to third, then approximately equal in size until penultimate, apical segment a bit longer but same width, a few small setae near apex of each segment. Tip of last segment of maxillary palpus weakly bifid, a few small setae towards tip. Penultimate segment of labial palpus shorter than apical, with two setae on slight bulge near apex (Fig. 28).

Pronotum: Much narrower than elytra, narrower behind, strongly extended forward at anterolateral angles, posterolateral angles square; punctures very sparse weak, a few larger punctures towards front edge; two strongly raised basal plicae, straight, reaching about half way along pronotum; row of long, thin setae in front half at edges and on forward extensions.

Elytra: Fused but may open slightly in preparations, lacking inner ridges; sides subparallel in middle; punctures very fine, sparse, each with a small seta, a few punctures with longer setae; moderately covered with micropunctures particularly at base, near suture and apex; sides of elytra quite strongly vertical; with row of long thin setae at edge, denser towards front. Epipleuron broad in front quarter, narrowing quite rapidly to middle, absent in apical half.

Ventral surface: Pronotal process arched in lateral view, highest point (viewed ventrally) between coxae, apical half parallel sided, tip weakly and bluntly pointed, narrowing between coxae, not reaching metathorax. Mesocoxae in contact in midline. Metathorax with a few small punctures; broadly triangular in midline in front; wings very narrow; narrowing to blunt point behind. Metacoxal plate with weakly raised central portion; metacoxal lines well separated, progressively diverging, reaching to about halfway to mesosternum; sparsely punctate; adpressed to first abdominal ventrite. Metacoxal plates and first and second ventrites fused but sutures evident, other ventrites free, ventrites three and four with central group of setae, otherwise virtually without setae; virtually impunctate.

Legs: Protibia about three times as broad at apex than at base; protarsi weakly expanded, second segment not much shorter than first, the fourth segment very small and hidden within deeply bilobed third segment, adhesive setae sparse; claws weak. Mesotrochanter sharply pointed, without setae on inner edge; mesofemur with two strong setae on hind margin at base (Fig. 17); mesotarsi slightly less strongly expanded than protarsi. Metatrochanter large, completely exposed, pointed, close to metafemur at apex (Fig. 18); metafemur relatively narrow, anterior edge weakly sinuate, impunctate, without spines; metatibia curved, thickening apically; metatarsal segments elongate, progressively smaller towards apical segment which is a little longer than penultimate, combined length of basal two segments approximately equal to other three; claws weak, outer one slightly smaller than other.

Male: Appendages and legs as for female. Median lobe of aedeagus moderately broad, concave above, narrowing to tip, without setae; parameres moderately broad, apical segment relatively long with small apical lobe (Fig. 33).

Etymology

This species is named after Kevin Morgan for his understanding of the hydrology and geochemistry of the palaeodrainage channels in Western Australia (Morgan 1993).

Remarks

The well marked pronotal plicae and pointed metatrochanters suggest a relationship with *N. pulpa*. The lack of an eye remnant and thinner antennae will separate it from this species. The distinctive, small, apical lobe on the paramere and the group of strong spines on the hind edge of the mesofemur reduced to two will separate it from all other *Nirridessus*.

Nirridessus bigbellensis sp. nov.

Types

Holotype: f. 'BES 7050, borefield monitoring bore PAT 7, Austin Downs Pastoral Station, 27°24'48"S 117°42'40"E, 12/5/99', coll. W. H. Humphreys & H. J. Hahn', slide mounted, WAM, registration number 26874.

Paratype: f. (partial specimen) as for holotype, slide mounted, SAMA.

Description (number examined, 2) Figs 5, 11, 12, 26.

Habitus: Length 3.0–3.2 mm.; relatively flat and broad, pronotum weakly narrowing at base; uniformly very light testaceous; hindwing vestigial, reduced to about two-thirds length of elytron.

Head: Broad, parallel sided in basal half, rapidly narrowing forward of area where eye would be; a small oval area delineated by dark sutures at each side in middle at edge; very weak reticulation; punctures sparse, weak, row of setiferous punctures running backwards from above antennal base. Antenna relatively thin, basal two segments broadest, third as long as second but narrower, fourth shorter, then approximately equal in size until apical segment which is longer and thinner than penultimate, a few small setae near apex of each segment. Maxillary palpus relatively thin, apical segment as long as other three combined, tip of last segment truncated, a few small setae towards tip. Apical segment of labial palpus twice length of penultimate which has two setae on slight bulge near apex (Fig. 26).

Pronotum: Broad, narrower than elytra, strongly constricted near base, strongly extended forward at anterolateral angles, posterolateral angles acute; punctures very sparse, weak, a few larger punctures towards front edge; basal plicae subobsolete; row of long, thin setae in front half at edges and on forward extensions.

Elytra. Not fused, lacking inner ridges; sides rounded; punctures small, very sparse, setiferous, a few punctures with longer setae; some micropunctures near apex; row of long thin setae laterally, denser towards front. Epipleuron broad in front fifth, narrowing quite rapidly to middle, absent in apical half.

Ventral surface: Pronotal process arched in lateral view, highest point (viewed ventrally) between coxae, apical half parallel sided, tip weakly and bluntly pointed, narrowing between coxae, not reaching metathorax. Mesocoxae in contact in midline. Metathorax with a few small punctures; broadly triangular in midline in front; wings narrow; rounded behind in midline. Metacoxal plates sparsely punctate; metacoxal lines, relatively close, weakly diverging, reaching to about two thirds of way to mesosternum; adpressed to first abdominal ventrite. Metacoxal plates and first and second ventrites fused, other ventrites free, ventrites three and four with central group of setae, otherwise virtually without setae; virtually impunctate.

Legs: Protibia elongate about three times as broad at apex than at base; protarsi weakly expanded, second segment not much shorter than first, the fourth segment very small and hidden within deeply bilobed third segment, adhesive setae moderate; claws moderately strong. Mesotrochanter parallel sided, apex rounded with a few setae on inner edge; mesofemur with six strong setae on hind margin at base (Fig. 11); mesotarsi more elongate than protarsi. Metatrochanter large, inner edge curved, outer edge straight, rounded at tip, well separated from femur at apex (Fig. 12); metafemur narrow, anterior edge weakly sinuate, impunctate, without spines; metatibia strongly curved, thickening apically; metatarsal segments elongate, progressively shorter towards apical segment which is a little longer than penultimate, combined length of basal two segments approximately equal to other three; claws weak.

Male: Not known.

Etymology

The name pertains to Big Bell Mine which draws its water from the aquifer in which the species lives.

Remarks

At over three millimetres in length the largest *Nirridessus* so far known. It also is more rounded in outline and less flattened than most. The thin maxillary and labial palpi, narrow metafemur and strongly acute posterolateral angles of the pronotum also set it apart.

Additional Specimens

Taxon 1

One small (length 1.5 mm) female specimen was collected at Lake Violet. Although close to *N. hinkleri* it probably represents a distinct species. More specimens, including males are needed to confirm this.

'BES 7160, observation bore for Pump 5,

Wiluna Gold Lake Violet Borefield, 26°41'08"S, 120°13'05"E 8/5/99, coll. W. F. Humphreys & H. J. Hahn', slide mounted, WAM, registration number 26875.

Taxon 2

Eight partial specimens of a large species (approximately 4.0mm long.), together consisting of pronotum, abdomen, elytra and male genitalia, but lacking head and all appendages, were collected at Lake Way. These represent a distinctive species of uncertain generic placement.

'BES 7222, Sample 3 Site 289 Hinkler calcrete east, unequipped water bore, 26°51'36"S, 120°18'05"E, 22/5/99, coll. W. F. Humphreys & H. J. Hahn', 4 in spirit, WAM, registration numbers 26876, 26877, 26878, 26879. 4 slide mounted, SAMA.

Larvae

Larvae of two very different taxa were collected at Austin Downs (type 1) and Lake Violet (type 2). Although bidessine they differ considerably from the two larval taxa described in our earlier paper (Watts and Humphreys 1999). In comparison to epigean bidessine larvae we would consider the four larval taxa to be generically distinct. None appear to belong to the very small *Kintingka kurutjutu* Watts and Humphreys. This conclusion is in conflict with the adult taxonomy. Association of larvae and adults and more collecting will be needed to resolve this.

Type 1: 1, 'BES 7021, borefield monitoring bore PAT 2, Austin Downs Pastoral Station , 27°23'44"S, 117°42'25"E, 11/5/99', slide mounted, WAM, registration number 26880; 1, 'BES 7050, borefield monitoring bore PAT 7, Austin Downs Pastoral Station , 27°24'48"S, 117°2'40"E, 12/5/99', in spirit, SAMA; 1, 'BES 7055 borefield monitoring bore PAT 1, Austin Downs Pastoral Station , 27°23'19"S, 117°43'33"E, 12/5/99', slide mounted, SAMA.

Type 2: 10, 'BES 7148, observation bore for

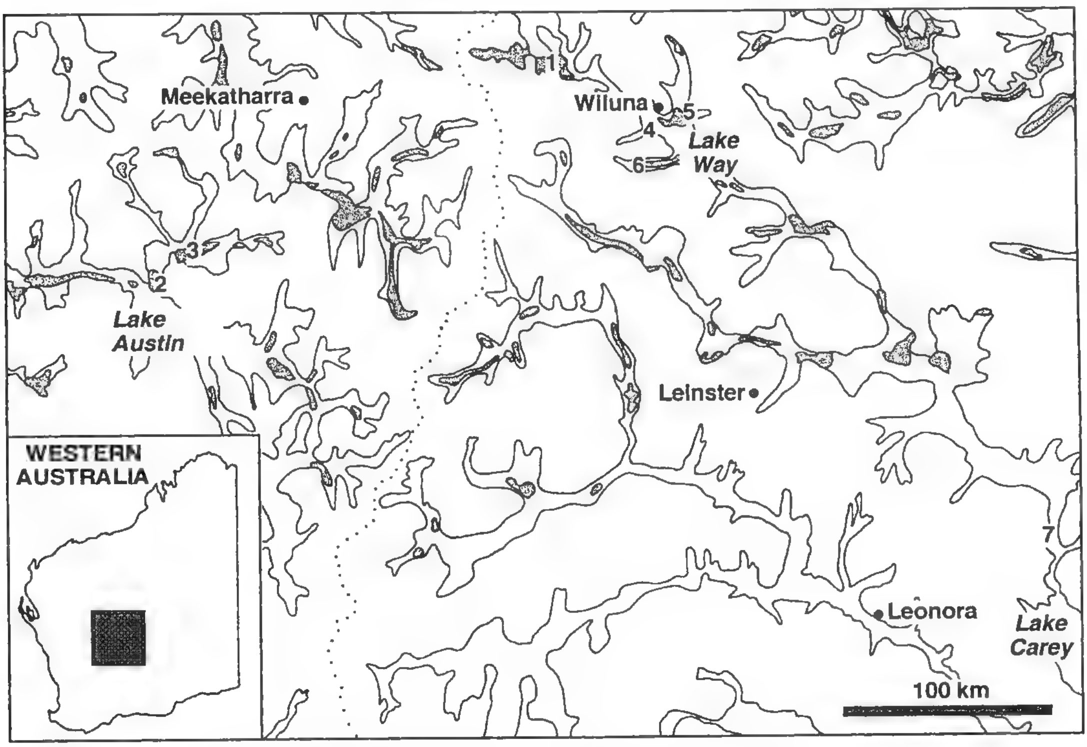


FIGURE 38. The distribution of stygal Dytiscidae in the Yilgarn Region. Groundwater calcrete deposits (shaded) are shown in the palaeodrainage channels (solid lines). The dotted line denotes the surface drainage divide (Beard 198); inland drainage to the east, Indian Ocean drainage to the west. The numerals denote discrete areas of calcrete (Table 1): 1, Paroo; 2, Austin Downs; 3, Cue; 4, Lake Violet; 5, North-east Lake Way; 6, Hinkler Well; 7, Mount Windarra.

TABLE 1. The distribution of stygal species of dytiscids amongst discrete calcrete bodies in the Yilgarn district of Western Australia.

Genus Calcrete body	*Tjirtudessus* W & H	*Nirridessus* W & H	*Kintingka* W & H
Western drainage			
Austin Downs	–	*bigbellensis* sp. nov.	–
Cue	[4]*magnificus* sp. nov.	[4]*cueensis* sp. nov.	–
Eastern drainage			
Paroo	[2]*eberhardi* W & H[1]	[2]*pulpa* W & H	[2]*kurutjutu* W & H
Lake Violet	–	undescribed sp.	–
NE Lake Way	*hahni* sp. nov.	*morgani* sp. nov.	–
Hinkler Well	–	*hinkleri* sp. nov.	–
Mount Windarra	[3]*lapostaae* W & H	[3]*windarraensis* W & H	–

[1] W & H = Watts & Humphreys 1999; [2] sympatric; [3] sympatric; [4] sympatric.

Pump 1, Wiluna Gold Lake Violet Borefield , 26°40'30"S, 120°13'55"E, 18/5/99'. 4 WAM, registration numbers 26881, 26882, 16883, 16884, 6 SAMA, slide mounted and in spirit; 1, same data but 'BES 7231, WAM, registration number 26885; 1, same data but 'BES 7242', WAM, registration number 26886. All collected by W. F. Humphreys and H. J. Hahn.

Discussion

Distribution

Dytiscid specimens were collected from six separate calcrete deposits: 1, Austin Downs (borefield for Big Bell Gold Mine); 2, Cue (former borefield for the town of Cue); 3, Paroo (pastoral station, detailed in Watts and Humphreys 1999); 4, Lake Violet at the northern end of Lake Way contains the borefield for Wiluna Gold Mine; 5, the Hinkler Well calcrete, the hydrogeochemistry of which is detailed in Mann and Deutscher (1978); and 6, the northeastern side of Lake Way adjacent to the Lakeway Uranium prospect (DCE 1981) (Fig. 38). Sites 1 and 2 drain towards the Indian Ocean whilst the remainder are to the east of the drainage divide in the Carey palaeodrainage system (sensu Morgan 1993) which drains to the interior of the continent. The distribution of the taxa by calcrete body is shown in Table 1.

No dytiscids or other large stygofauna were taken from open, hand dug, pastoral wells even if they were adjacent to narrow bores containing stygal dytiscids and other stygofauna. Despite sampling widely in non-calcrete aquifers no dytiscids were collected in other than calcrete aquifers, which confirms the conclusion of our earlier, much more restricted sampling, that the beetle and other larger stygofauna is restricted to aquifers in areas of calcrete (W. F. Humphreys unpublished; Watts and Humphreys 1999). In addition, this study extends the range of waters inhabited by stygal dytiscids, and other stygofauna, to saline water with a salinity of at least 20 g l^{-1}.

These discoveries significantly extend the known range of both *Tjirtudessus* and *Nirridessus* from the inland draining Lake Way/Lake Carey palaeodrainage channel to the seemingly never-connected Murchison palaeodrainage system that drains westward to the Indian Ocean. No Dytiscidae were discovered in stygofauna-rich calcrete aquifers in the Pilbara region. Since only about 9% of the major calcrete deposits in the palaeodrainage channels of Western Australia alone (Humphreys 1999) have been sampled for stygofauna it is likely that additional subterranean Dytiscidae remain to be discovered in Australia.

Associated fauna

The dytiscids were collected amongst a diverse stygofauna comprising mainly phreodrillid Oligochaeta, bathynellids (Syncarida), Ostracoda, cyclopoid and harpacticoid Copepoda, crangonyctoid and ceinid Amphipoda and *Haloniscus* (Oniscoidea: Isopoda).

Water quality

Fresh to saline groundwaters occur widely in calcretes and may be reached as close as two metres from the surface to more than 100 m below the surface. The calcrete aquifer itself may vary up to 30 m in thickness (Barnett and Commander

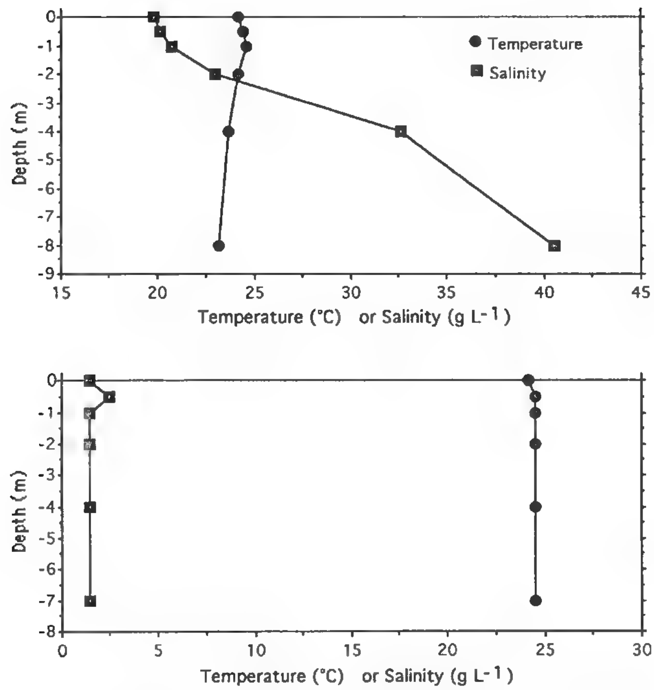


FIGURE 39. Physiochemical profiles in some aquifers from which dytiscid beetles were collected. Upper, site 286 NE Lake Way; lower, site 289 Hinkler East.

1985), but those sampled in the Yilgarn are typically thin and the groundwater is close to the surface (Table 2). The area is arid and rainfall (c. 200 mm per year) is irregular predominately as episodic heavy falls (Sanders 1973) which recharge the calcrete aquifers through the porous, often karstic (Barnett and Commander 1985), surfaces. Indeed, groundwater calcretes are carbonate deposits forming near the water table in arid lands as a result of concentration processes by near-surface evaporation and they are associated with slow moving groundwater that fluctuates widely in depth (Jacobson and Arakel 1986; Morgan 1993). In consequence the groundwater table varies quite widely between storm events and markedly in salinity. The dytiscids were collected from water of variable quality (Table 2) with samples collected from fresh water (salinity < 1000 mg l^{-1}) as well as saline conditions (salinity > 20 000 mg l^{-1}). At some locations the water was well stratified with marked changes in the physico-chemical conditions with depth, while at others the vertical profile was less marked (Fig. 39; Table 2).

Considerable seasonal variation occurs in the salinity of at least some of the habitats (foot note to table 2) but the effect of this on the distribution of the stygofauna is unknown. Marked seasonal changes in numbers have been reported for stygal dytiscids inhabiting alluvial aquifers near rivers (Ordish 1976), and it is known that changes to the water table and the direction of groundwater flow have profound effects on the location of such populations (Richoux and Reygrobellet 1986).

Palaeogeography and hydrology

While much is still to be learnt of these stygal dytiscids, it is worthwhile at this stage to consider the palaeogeographic and hydrological setting in which this fauna, and that reported by Watts and Humphreys (1999), occurs.

The Western Shield of Western Australia is divided from north to south by a drainage divide that separates the rivers, some still active, draining to the Indian Ocean, from those draining to the east and which are now largely inactive and disorganised (Beard 1998). The present drainage, now mostly a palaeodrainage system, formed during the Mesozoic when the Western Shield was attached to Antarctica (Beard 1998; van de Graaf *et al.* 1977; Morgan 1993). The sediments infilling the palaeochannels are mostly Eocene or later but the age of the calcretes is unknown. Morgan

TABLE 2. Physico-chemical characteristics of sites from which stygal dytiscids were recorded.

Site	Sample depth (m)	Salinity g L^{-}	Temperature °C	Dissolved O_2 % sat	mg L^{-1}	pH	[2]Depth to water (m)	[2]Depth of water(m)
PAT2 – Austin Downs	–	5[1]	–	–	–	–	4.8	6
PAT1 – Austin Downs	–	8[1]	–	–	–	–	8	4.8
Old Cue town bore	–	5	25	50.5	3.9	–	4	0.5
GSWA5 surface- Paroo	–	1.38	26.7	59.7	4.5	7.7	3.6	[3]4
GSWA5 deep- Paroo	–	–	–	49	3.7	–	–	–
GSWA6 surface- Paroo	–	0.77	24.8	59.7	4.6	7.5	5	[3]6.6
GSWA6 deep- Paroo	–	0.79	24.7	43.5	3.4	7.5	–	–
GSWA15 small- Paroo	–	0.53	26	59.2	4.5	8.4	3	[3]8
GSWA15 small- Paroo	–	0.6	25.3	38.6	3	7.9	–	–
SB 32/1 – Hinkler west	–	1.66	26.9	79.2	6	7.7	4.8	2
TPB 25/4 – Hinkler west	–	2	–	–	–	–	4.8	34
OB Pump 1 – Lake Violet	–	2.36	24.6	88.7	7	8.2	4.8	5.6
262 – NE Lake Way	–	4.46	25.7	86.1	6.6	7.6	4	1.6
286 – NE Lake Way	0	19.8	24.2	23	1.8	–	2	20
286	0.5	20.1	24.4	–	–	–	–	–
286	1	20.7	24.6	–	–	–	–	–
286	2	23	24.2	–	–	–	–	–
286	4	32.6	23.7	–	–	–	–	–
286	8	40.5	23.2	–	–	–	–	–
288 – Hinkler east	0	1.46	24.2	68.6	5.4	8.3	2.4	19
288	0.5	2.43	24.5	–	–	–	–	–
288	1	1.43	24.5	–	–	–	–	–
288	2	1.42	24.5	–	–	–	–	–
288	4	1.42	24.5	–	–	–	–	–
288	7	1.42	24.5	–	–	–	–	–
289 – Hinkler east	0	1.56	24.4	74.4	5.9	8	2.4	19
289	0.5	1.7	24.6	–	–	–	–	–
289	1	2.04	24.5	–	–	–	–	–
289	2	2.1	24.5	–	–	–	–	–
289	4	2.12	24.5	–	–	–	–	–
289	8	2.15	24.5	–	–	–	–	–

[1] PAT1 and PAT2 have annual salinity variation between 5–9 g l^{-1} and 5–22 g l^{-1} respectively as determined from borefield monitoring by Big Bell Mine. [2] Depth approximate. [3] To base of calcrete (Sanders 1972).

(1993) considered it likely that they formed from the start of the Oligocene following the onset of the continental aridity but they have probably been remobilized and redeposited. As this process is continuing it is not possible to date the calcretes using standard radiometric methods.

The Yilgarn Craton covers 750,000 km^2 of southwestern Australia between latitudes 34° and 25° S and has mostly not been submerged by the sea since the beginning of the Mesozoic. The northeastern half is semi-arid with unreliable rainfall that may fall throughout the year.

The central watershed traverses a palaeosurface barely modified since the Cretaceous (Beard 1998). This central watershed is of fairly uniform elevation traversed only by a few minor gaps or low points that may be indicative of a change to the drainage patterns in the distant past. One of these is on Killara Station where a col, 50–100 m below the level of the adjacent watershed, separates the Murchison and the Carey (Lake Way-Lake Carey in Watts and Humphreys 1999) palaeodrainage systems (Beard 1998) which together encompass the entire distribution of the Australian stygal dytiscids known to this time. While it is tempting to invoke some significance of this gap to the biogeography of the stygofauna, this minor gap may merely reflect the trend of less resistant Proterozoic rocks (Beard 1998).

The collection sites at Cue and Lake Austin

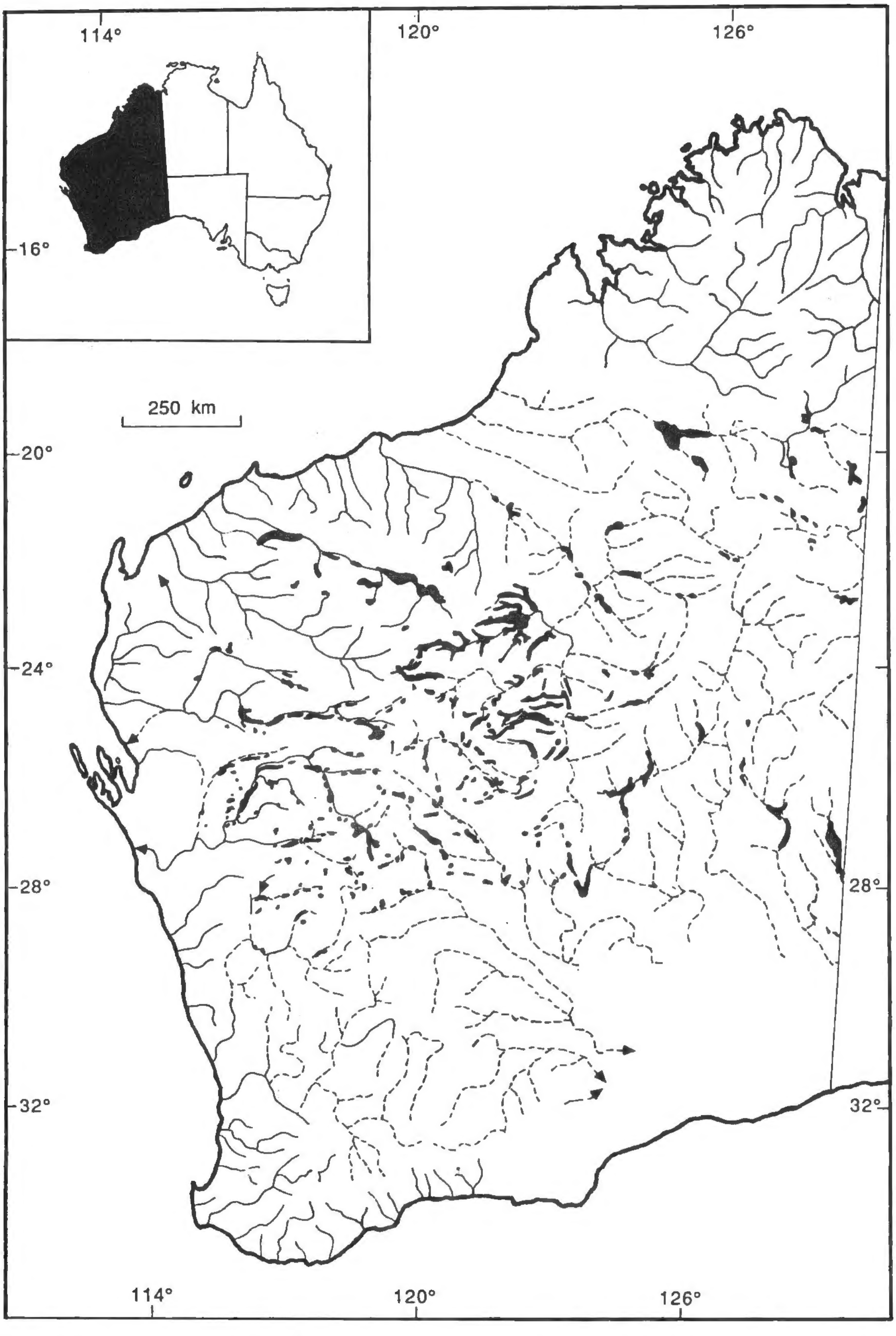


FIGURE 40. The distribution of groundwater calcrete aquifers in Western Australia (from Humphreys 1999). Modern and palaeo-drainage (respectively, continuous and dashed lines) and calcrete areas (black) are shown. Derived from data in Geological Survey (1989), drawn by Julianne Waldock on a base map provided by Philip Commander (further details in Humphreys 1999).

(containing *Tjirtudessus magnificus*, *Nirridessus cueensis* and *Nirridessus bigbellensis*) are separated from those to the east (containing *Tjirtudessus hahni*, *Nirridessus hinkleri* and *Nirridessus morgani* plus the five species in Watts and Humphreys 1999) by the continental water divide (Beard 1998) between the inland drainage and that draining to the Indian Ocean. As the water divide is also the approximate water divide for the palaeodrainage systems that date from at least the Cretaceous no subterranean hydrological connection is likely to have occurred. The presence of congeneric stygal species on either side of this water divide suggests that the fauna colonised groundwater from a widespread epigean ancestor, possibly driven by the increasing aridity of central Australia since the Eocene.

Groundwater calcretes stretch through arid central Australia as far as the border of the Northern Territory and Queensland (Fig. 40; Humphreys 1999). Similar calcretes occur on the Pilbara Craton which comprises much of the rest of the Western Shield of Australia, and there also, each discrete calcrete area sampled so far contains a distinct stygofauna (Poore and Humphreys; W. F. Humphreys and S. M. Eberhard, unpublished; S. M. Eberhard, unpublished; S. M. Eberhard and W. F. Humphreys unpublished). However, no dytiscids have been taken from the Pilbara Craton.

Each of the seven discrete, but sometimes adjacent, calcrete areas sampled from the palaeodrainage lines on the Yilgarn Craton (herein and Watts and Humphreys 1999) contains a distinct assemblage of dytiscids (and probably other stygofauna). The data represented here contains samples from only two of 42 major calcretes areas in the upper Murchison catchment, and five out of 18 major calcrete areas in the Carey palaeodrainage system. In Western Australia alone there are about 210 major calcrete areas divided amongst about five major drainage systems (Fig. 40)

Each calcrete sampled in the Yilgarn (and Pilbara) containing stygofauna has a unique stygofaunal community and as only a small proportion of the available calcrete areas have been sampled, this suggests that there is considerable biodiversity to be unearthed amongst the dytiscids and in the arid zone stygofauna generally.

Changes to the water table and the direction of groundwater flow may have profound effects on the location of populations of stygal dytiscids (Richoux and Reygrobellet 1986) and unique stygal assemblages, including Dytiscidae, may be lost if groundwater pollution occurs (Uéno 1996). As the stygofaunas are unique with circumscribed distributions and they occur in systems of potential or actual resource developments, they present a real challenge for innovative environmental management. Furthermore, these calcrete aquifers are sufficiently replicated and contain a diversity of fauna sufficient to test independently theories and processes that gave rise to the vicariance within these systems.

While much work is needed to start to understand distribution patterns, the faunistic distinctiveness of the groundwater calcrete aquifers is consistent with the evolution of the hydrogeological system in the palaeodrainage channels as interpreted by Morgan (1993). In essence, Morgan argues that in the palaeorivers north of latitude 30°S separate geochemical systems develop associated with the formation of each salt lake (playa) along a palaeodrainage system. In the groundwater there is a well defined change in common ion ratios developed with increasing salinity marked especially by a relative increase in chloride and sulphate with respect to other ions—this may contribute to the heterogeneity in stygofauna distribution within a given calcrete area reported by Poore and Humphreys (1998). As it is related to the rate of movement of the groundwater, this increase in salinity and relative chloride/sulphate content is both spatial and temporal because the change takes place between widely separate intake and outflow locations. This hydrochemical trend commences at the headwaters of each recharge system, such as a large alluvial fan, and completes its cycle at the evaporation outlet marked by the lower boundary of the calcrete with a salt lake. The main channel calcretes are formed at the downstream end of an individual hydrochemical system and immediately upstream of an evaporation outflow area forming a salt lake (Morgan 1993). Several similar hydrochemical cycles may occur along a single palaeodrainage system.

The marked age and stability of the palaeodrainage systems themselves, coupled with the repeated cycles of fresh to hypersaline (>200 $g\ l^{-1}$) groundwaters along the length of each palaeodrainage system would effectively isolate each stygal assemblage within the region where groundwater characteristics are suitable for their development.

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