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*BY S. BARKER* & C. L. BELLAMY†*

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Key Words: Australia, Coleoptera, Buprestidae, Cisseis, Stanwatkinsius, new genus, new species.

*Transactions of the Royal Society of S. Aust.* (2001), **125**(1), 1-14.

# *STANWATKINSIUS*, A NEW GENUS OF AUSTRALIAN JEWEL BEETLES (COLEOPTERA: BUPRESTIDAE: AGRILINAE) WITH A KEY TO KNOWN SPECIES

by S. BARKER* & C. L. BELLAMY†

## Summary

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Seven species of jewel beetles previously placed in the genus *Cisseis* (Coleoptera: Buprestidae: Agrilinae) are recognised as different and a new genus *Stanwatkinsius* is proposed to accommodate them, their synonyms and nine new species. The species ascribed to the new genus are *Cisseis perplexa* (type species), *C. careniceps*, *C. cincta*, *C. constricta*, *C. lindi*, *C. subcarinifrons* (= *C. occidentalis*), *C. uniformis* (= *C. coraeboides*), *Stanwatkinsius crassus* sp. nov., *S. demarzi* sp. nov., *S. grevilleae* sp. nov., *S. kerneti* sp. nov., *S. powelli* sp. nov., *S. macmillani* sp. nov., *S. rhodopus* sp. nov., *S. speciosus* sp. nov. and *S. viridimarginalis* sp. nov. A key is provided for the identification of these species. The relationships of the genus to other members of the tribe Coraebini are discussed.

KEY WORDS: Australia, Coleoptera, Buprestidae, *Cisseis*, *Stanwatkinsius*, new genus, new species.

## Materials and Methods

Specimens examined were borrowed from or are deposited in the following institutions and collections:

ANIC - Australian National Insect Collection, Canberra.
BMNH - The Natural History Museum, London.
CLBC - C. L. Bellamy collection, Los Angeles, California.
HDWA - H. Demarz, Woodridge, Western Australia.
MGWA - M. Golding, Beverley, Western Australia.
MHSA- M. Hanlon, Sydney, New South Wales.
MNHN- Muséum National d'Histoire Naturelles, Paris.
MPWA - M. Powell, Melville, Western Australia.
NMVA - National Museum of Victoria, Melbourne, Victoria.
SAMA - South Australian Museum, Adelaide, South Australia.
SWLA - S. Watkins, Lismore, New South Wales.
WAMA - Western Australian Museum, Perth, Western Australia.

Type numbers listed below for specimens from the Blackburn collection, BMNH, are not type accession numbers assigned in the BMNH system, but rather Blackburn collection type numbers.

All of the specimens were examined under a binocular microscope. They were photographed with a Nikon 35 mm camera with extension tubes and the transparencies were scanned and digitally manipulated by computer using Adobe Photoshop. Specimens were prepared for electron microscopy by vacuum coating with gold and then photographed using an Hitachi S-450 Scanning EM.

## Introduction

The buprestid genus *Cisseis* Gory & Laporte, 1839 (Agrilinae: Coraebini) occurs thoughout Australia and its distribution extends north and east into New Guinea, the Solomon Islands, and the Philippine archipelago. In Australia, most species of *Cisseis* are associated with *Acacia* species; the larvae bore into decaying wood and the adults are mostly foliage feeders. Occasionally the adults visit flowers of the host plants and other locally blooming species. The last revision of Australian *Cisseis* was by Carter (1923); subsequent collecting has revealed many undescribed species. In the course of re-examining species attributed to the genus, we found that seven species originally placed in *Cisseis* are different from all other described species. Blackburn (1891:300), when describing *Cisseis perplexa* Blackburn, the first of the seven, outlined the differences between it and typical *Cisseis* species. Stan Watkins, a prolific collector in NSW, drew our attention to an undescribed species allied to *Cisseis perplexa* differing from typical *Cisseis* spp.; we have recognised eight additional species which fit this category. Some of the species are associated with either *Casuarina* or *Allocasuarina* spp. Many of the others have been

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found on the leaves of *Grevillea* spp. and *Hakea* spp. The major morphological departure from *Cisseis* is the structure of the ovipositor, which is similar to but not identical with the structure of the ovipositor in *Meliboeithon* Obenberger. Both have incurving setae, sharp in *Meliboeithon*, blunt at the top and sharp further down in all species of this distinct group. *Cisseis* species have a tubular ovipositor without incurving setae. This difference and others have prompted us to erect a new genus for their placement. We propose the name *Stanwatkinsius* for the new genus.

## *Stanwatkinsius* gen. nov.

Type species. *Cisseis perplexa* Blackburn, 1891 (present designation).

Diagnosis: Small, length less than 10 mm; subcylindrical; general form somewhat resembling *Astraeus* Gory & LaPorte and *Meliboeithon*; surface punctate and/or transversely rugose, iridescent, sparsely pubescent, the sexes are dichromatic in some species.

*Description*

Head: eyes small, widely separated, inner margins subparallel; frontovertex broad, transverse, often with feeble longitudinal medial costa; antennal insertions large, moderately to widely separated, with sinuate carina dorsad to each (Fig 1); epistome declivous ventrad of antennal insertions; gena with single rounded acute projection below eye; with narrow depression to receive basal antennomeres in repose; labrum punctate; mandible robust. Antennae triangularly serrate from antennomere 4 or 5. Pronotum wider than long, widest at posterior margin; anterior margin evenly arcuate; posterior margin bisinuate; lateral margin narrowing before subacute lateroposterior angle, even before narrowing to anterior margin; disc flattened medially, evenly rounded laterally; one preapical carina to well before midpoint extending arcuately away from lateral margin and extending anterior to lateroposterior angle to well beyond midpoint. Scutellum moderate size, subcordiform, wider than long; anterior margin even, transverse; posterior margin strongly attenuate. Elytra much longer than wide; widest near posterior third, but wider opposite humeri than at posterior margin of pronotum; lateral margins subparallel from opposite humeri to about mid-point, widening to posterior third before gradually narrowing to separately subtruncate apices; posterior portion of lateral margin serrate or serrulate; epipleuron short, extending opposite length of metepisternum, separated from disc by small carina. Prosternal process with truncate apex and two acute lateral projections posterad of procoxae; metepimeron not visible; anterior margin of metacoxal plate concave medially; posterior margin feebly emarginate; abdominal sterna each progressively shorter than preceding, sutural margins feebly arcuate medially; sterna 3-5 with visible lateral margins each with prelateral straight groove, complete around margin of 5. Femora fusiform, tibiae longer than femora, each with pair of spines at distal apex; metatibiae with setigeris on distal portion; tarsi 1-4 each with ventral pulvillus, each pulvillus broader than the previous one, those on tarsomeres 3 and 4 bilobed; tarsomere 5 with claws feebly appendiculate and notched basally and asymmetric, outer claw thicker than inner claw. Genitalia: male, all very similar relatives; ovipositor "coraebine type", similar to that figured in Bellamy (1988: 423, Fig. 61) for *Meliboeithon* except ventral setae blunt not sharp. Ovipositor in *Cisseis* in form of

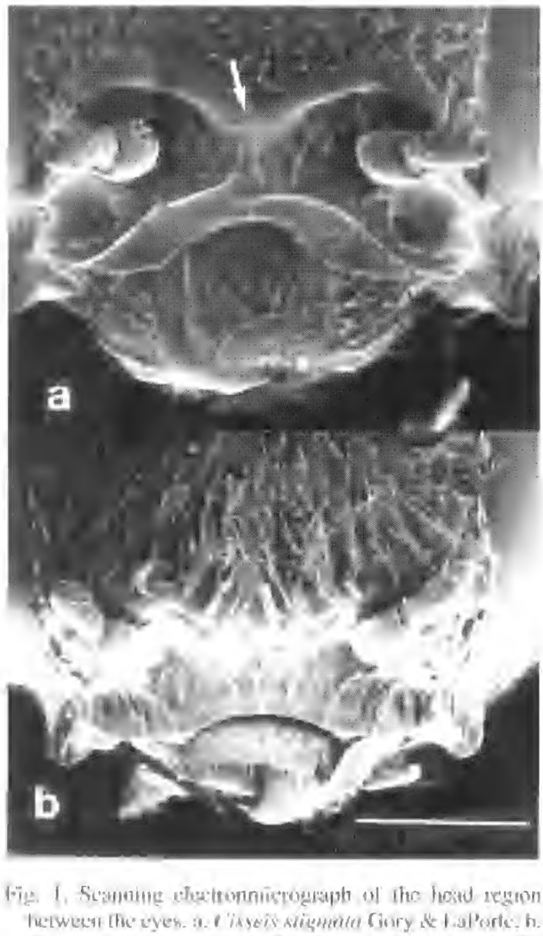

Fig. 1. Scanning electronmicrograph of the head region between the eyes. a. *Cisseis stigmata* Gory & LaPorte; b. *Stanwatkinsius perplexus* (Blackburn). In each only the two basal antennomeres are present; the arrows indicate the junction between the frons and the epistome. Scale bar = 0.5 mm.

flattened tube, without ventral setae (Bellamy 1988: 416).

**Remarks**

*Stanwatkinsius* differs from *Cisseis* in the following combination of characters and character states. The plant associations of the various species: most are associated with species of *Grevillea* or *Hakea*; some with either *Casuarina* or *Allocasuarina*, and differ from the general *Cisseis* species association with mainly various species of *Acacia*. The morphology of the ovipositor differs between these genera. In *Cisseis* it is a flattened tube with short, paired styli. In *Stanwatkinsius* it is a scoop formed from incurving setae. None of the species of *Stanwatkinsius* has spots on the elytra formed from setae as in various *Cisseis*, *Neospades* Blackburn and *Pachycisseis* Théry species. All have plain metallic colouration. In *Stanwatkinsius* the mandibles are more robust and a different shape from those in *Cisseis*; the antennal insertions are higher than in *Cisseis*; in *Cisseis* the edge of the frons lacks punctures and is very distinct, there is a step between this structure and the epistome whereas in *Stanwatkinsius* the junction between the frons and epistome is indistinct and the fovea surrounding the insertion of the basal antennomere is less prominent (Fig. 1). In *Stanwatkinsius* the labrum is narrow and has a brush of stout adpressed setae along the apical margin. On the pronotum, the dorsal carina does not reach the apical margin in any species, whereas in *Cisseis* the dorsal carina meets the apical margin in all but a few species. The asymmetrical tarsal claws are quite different from *Cisseis* species and uncommon in buprestids in general. One example of tarsal claw asymmetry in coraebines was discussed by Bellamy (1990) for the Asian and Philippine genus *Coraebosoma* Obenberger.

**Key to *Stanwatkinsius* species**

1. Body all green ♂ & ♀ . . . . . . . . . . . . . . . . . . . . . . 2
   Body other than green . . . . . . . . . . . . . . . . . . . . . 3
2. ♂ & ♀ dark green, southern species . . . . . . . . . . . . . . . . . . . . . . *uniformis* (Kerremans)
   ♂ bright green, northern species . . . . . . . . . . . . . . . . . . . . . . . . . *kerneli* sp. nov.
3. ♂ head green apically, dark blue basally; ♀ head coppery . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4
   ♂ head other than green & blue . . . . . . . . . . . . 5
4. ♂ & ♀ pronotum coppery . . . *speciosus* sp. nov.
   ♂ pronotum dark blue; ♀ pronotum coppery . . . . . . . . . . . . . . . . . . . . . . *constrictus* (Blackburn)
5. ♂ & ♀ head purple or purple-blue, ventral surface purple . . . . . . . . . . . . . . *powelli* sp. nov.
   Head other than purple . . . . . . . . . . . . . . . . . . 6
6. ♀ head & pronotum rosy, elytra dark blue . . . . . . . . . . . . . . . . . . . . . . . . *rhodopus* sp. nov.
   ♀ head & pronotum other than rosy . . . . . . . 7
7. ♂ & ♀ head, pronotum ventral surface bronze . . 8
   ♂ & ♀ head, pronotum ventral surface other than bronze . . . . . . . . . . . . . . . . . . . . . . . . . . . 9
8. ♂ & ♀ elytra bronze . . . *perplexus* (Blackburn)
   ♂ elytra blue; ♀ elytra bronze with red apical margins . . . . . . . . . . . . . . . . . . *catenticeps* (Carter)
9. ♂ & ♀ head, ventral surface green, pronotum & elytra mostly brown . . . *subcarinifrons* (Thomson)
   ♂ & ♀ elytra other than all brown . . . . . . . . 10
10. Elytra with green lateral margins . . . . . . . . . . 11
    Elytra with red lateral margins . . . . . . . . . . . . 12
11. ♂ head, pronotum blue . . . *macmillani* sp. nov.
    ♂ head green, pronotum medially brown laterally green; ♀ head & pronotum brown . . . . . . . . . . . . . . . . . . *viridimarginalis* sp. nov.
12. ♂ & ♀ head, pronotum coppery . . . . . . . . . . . . . . . . . . . . . . . *lindi* (Blackburn)
    ♂ & ♀ head, pronotum other than coppery . 13
13. ♂ head, pronotum, ventral surface green . . . 14
    ♂ head, pronotum, ventral surface blue . . . . 15
14. ♀ head bronze-yellow; small, 5-6 mm . . . . . . . . . . . . . . . . . . . . *cinctus* (Kerremans)
    ♀ head green; larger, >7 mm . . *crassus* sp. nov.
15. Smaller species, head finely punctured; occurs on WA coastal plain . . . . . . . . *demarzi* sp. nov.
    Larger species, head coarsely punctured; occurs inland WA . . . . . . . . . . . . . . *grevilleae* sp. nov.

***Stanwatkinsius perplexus*** (Blackburn, 1891), comb. nov.
(FIGS 1b, 2a)

*Cisseis perplexa* Blackburn 1891:300, Kerremans 1903:230, Carter 1923:167; 1929:279, Obenberger 1934:852.

*Holotype*: ♀, Blackburn (T 2185), BMNH, examined.

*Other specimens examined*: WA: ♂, Wannamal, 8.ix.1970, S. Barker, SAMA; ♂, Korrelocking, 22.ix.1970, S. Barker, SAMA; 2 ♂♂, Quairading, 7.ix.1970, S. Barker, SAMA; ♂, 77 km E T.O. Old York Rd, 7.xi.1970, S. Barker, SAMA; 5 ♂♂, 4 ♀♀ South Tammin Flora Res., 8.xi.1970, S. Barker, CLBC & SAMA; 2 ♀♀, Wannamal, 10.xi.1970, S. Barker, SAMA; ♀, 77 km E T.O. Old York Rd, 21.xi.1970, S. Barker, SAMA; 2 ♂♂, ♀, South Tammin Flora Res., 6.i.1971, S. Barker, SAMA; ♀, 3 km S Israelite Bay T.O. SW Mt Ragged, 10.xii.1974, S. Barker, SAMA; ♀, 3 km E Norseman, 14.xii.1974, S. Barker, SAMA; ♀, South Tammin Flora Res., 20.xii.1975, S. Barker, SAMA; ♀, South Tammin Flora Res., 8.x.1976, S. Barker, SAMA; ♀, 25 km E Lake Grace, 19.ix.1979, F.H. Uther Baker, SAMA, SA: 4 ♂♂, ♀, 18 km E Kimba, 8.x.1979, S. Barker, SAMA; ♂, Lake Gilles C.P. E Kimba, 14.x.1990, S. Barker, SAMA; ♂, ♀, no data, SAMA.

*Male*

Size: 8.0 x 2.9 mm (20).

Colour: Head mostly coppery-purple, green at base, all green in a few specimens. Antennae bronze. Pronotum mostly coppery-purple, anterior margin green. Scutellum coppery-purple. Elytra bronze. Ventral surface and legs coppery-purple.

Shape and sculpture: Head deeply punctured, setose, low medial carina from apex, projecting into median impressed line post-medially, reaching base. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum striolate, apical margin projecting medially over half its length, basal margin bisinuate; dorsal carina diverging from lateral margin at base, convex, approaching but not reaching angle, laterally setose. Scutellum scutiform, without punctures, flat, basal margin slightly concave. Elytra heavily striolate basally, rugose along suture, scutellate laterally; more or less parallel-sided, narrowed post-medially to rounded apices, apical margin sub-serrate. Ventral surface scutellate, densely covered by long setae as are legs.

*Female*

Size: 8.5 x 3.0 mm (17).

Colour: Head coppery-purple. Pronotum bronze with coppery-purple reflections. Elytra bronze. Ventral surface and legs coppery purple.

Shape and sculpture: as in male.

*Distribution*

WA: Common in drier heath areas associated with *Allocasuarina* spp. SA: Kimba on *Allocasuarina helmsii* (Ewart & M. Gordon).

**Remarks**

This species is the largest in the genus and the only one that is entirely bronze.

***Stanwatkinsius careniceps*** (Carter, 1923), comb. nov.
(FIG. 2b)

*Cisseis careniceps* Carter 1923: 171; 1929:278. Obenberger 1934:843.

*Holotype*: 3 ♂♂ syntypes, BMNH, examined.

*Other specimens examined*: WA: 2 ♂♂, 2 ♀♀, 48 km E Geraldton, 22.ix.1958, S. Barker, SAMA; ♀, Tuttaning, 1.i.68, S. Barker, SAMA; ♀, Ballidu, 16.ix.1970, S. Barker, SAMA; ♂, Payne's Find, 17.ix.1970, S. Barker, SAMA; ♀, Wialki, 19.ix.1970, S. Barker, SAMA; 3 ♂♂, 53 km W Mullewa, 20.ix.1996, T.M.S. Hanlon, MHSA; 3 ♂♂, Watheroo, 3.xi.1990, H. Demarz, HDWA; ♂, Tammin Res., 28.x.1975, H. Demarz, HDWA; ♂, ♀, 3 km E Tallering Homestead, 23.xi.1989, S. Barker, CLBC; ♀, Tallering stn., 23.ix.1989, on *Allocasuarina campestris*, Barker/Watkins, SWLA; ♂, ♀, 13 km N Galena, 8.ix.1998, on *Allocasuarina campestris*, T.M.S. Hanlon, MHSA; ♀, 39 km N Galena, 8.ix.1998, on *Allocasuarina campestris*, T.M.S. Hanlon, MHSA.

*Male*

Size: 8.3 x 2.8 mm (11).

Colour: Head, antennae, pronotum and scutellum bronze. Elytra either deep violaceous with red margin around the apices or grey-blue with red margin around the apices and red along suture on each elytron from middle to apex. Ventral surface, legs bronze.

Shape and sculpture: Head deeply punctured, setose, with a median apical carina extending to base as impressed line. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum deeply striolate, apical margin broadly projecting medially, basal margin bisinuate, dorsal carina separated widely from margin except at base, not reaching apical margin; laterally setose. Scutellum flat, without punctures. Elytra striolate, laterally parallel-sided from base, rounded post-medially, then narrowed to rounded apices. Ventral surface striolate, with moderately long setae.

*Female*

Size: 8.7 x 3.0 mm (8).

Colour: Head, antennae, scutellum bronze. Elytra bronze, apical margin red. Ventral surface and legs bronze.

Shape and sculpture: as in male.

*Distribution*

WA: most common on the northern edge of the wheatbelt. Associated with *Allocasuarina campestris* (Diels).

**Remarks**

*Stanwatkinsius careniceps* and *S. perplexus* are closely allied species. Males are easily distinguished by their different colour combination. The females of this species are distinguished from females of *S. perplexus* by their elytra which have a red apical mark, absent in the other species.

*Stanwatkinsius cinctus* (Kerremans)
(FIG. 2o)

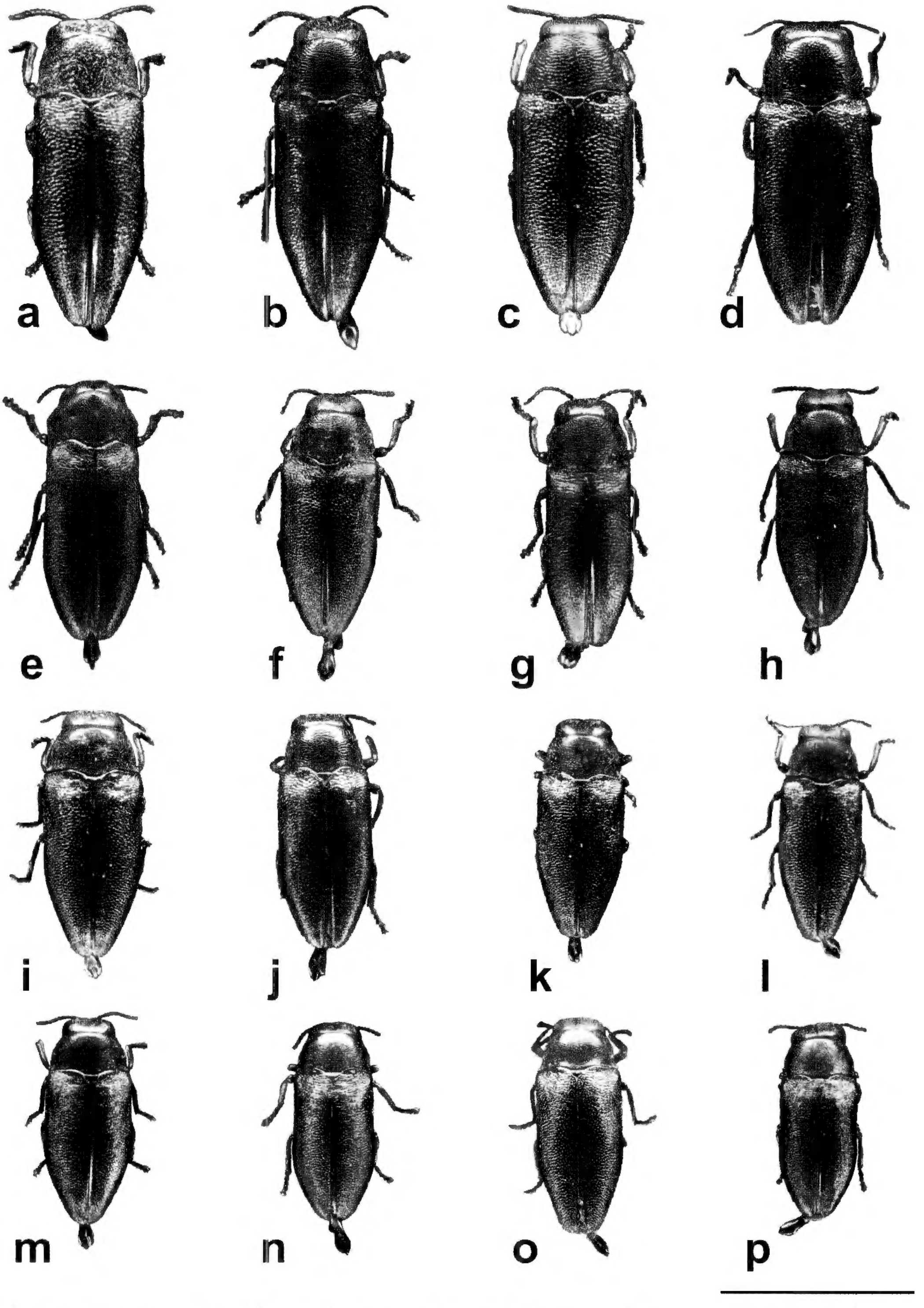


Fig. 2. Habitus illustrations of the following *Stanwatkinsius* species: a. *Stanwatkinsius perplexus* (Blackburn). b. *S. careniceps* (Carter). c. *S. crassus* sp. nov. d. *S. rhodopus* sp. nov. e. *S. powelli* sp. nov. f. *S. speciosus* sp. nov. g. *S. kermeti* sp. nov. h. *S. constrictus* (Blackburn). i. *S. lindi* (Blackburn). j. *S. viridimarginalis* sp. nov. k. *S. grevilleae* sp. nov. l. *S. macmillani* sp. nov. m. *S. demarzi* sp. nov. n. *S. uniformis* (Thomson) o. *S. cinctus* (Kerremans). p. *S. subcarinifrons* (Thomson). Scale bar = 5 mm.

*Cisseis cincta* Kerremans 1898:166; 1903:229. Carter 1923:167 (syn. *subcarinifrons*); 1929:279. Obenberger 1934:855 syn. nov.

*Holotype*: ♀, *Cisseis cincta* Kerremans, Australia, Oberthur, BMNH, examined.

*Other specimens examined*: WA: 3 ♂♂, ♀, Coorow, W.A., 245 km N, on non-prickly *Hakea*, 16.x.38, Du B. ANIC; ♂, Marloo stn., 1931-1941, A. Goerling, ANIC; ♂, 17 km S Northampton, 1.x.1981, I.D. Naumann & J.C. Cardale, ANIC; 2 ♂♂, 80 km N Moora, 20.x.1996, Kershaw/Golding, MGWA; ♂, Woodridge, intercept trap, 10.xi.1998, H. Demarz, SAMA; 2 ♂♂, 13 km N Galena, 11.ix.1998, T.M.S. Hanlon, MHSA.

*Male*

Size: 5.6 x 2.2 mm (10).

Colour: Head green. Antennae: antennomeres 1-2 green; 3-11 black with green reflections. Pronotum, scutellum green. Elytra dark brown medially, bronze-red laterally. Ventral surface and legs green.

Shape and sculpture: Head punctured, shallow median sulcus at the apex extending as impressed line reaching base. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum striolate; apical margin broadly projecting medially, basal margin bisinuate; dorsal carina diverging from lateral margin at base then curving towards it post-medially, not reaching the margin. Scutellum flat, without punctures, basal margin concave. Elytra shallowly punctured along suture rest scutellate; laterally parallel-sided from base, rounded post-medially and narrowed to rounded apices. Ventral surface shallowly scutellate; very short setae.

*Female*

Size: 5.6 x 2.2 mm (2).

Colour: Head yellow-bronze. Antennae: antennomeres 1-2 yellow-bronze; 3-11 black with green reflections. Pronotum, scutellum yellow-bronze. Elytra dark brown medially, bronze-red laterally. Sternum and legs yellow-bronze. Abdomen green.

Shape and sculpture: as in male.

*Distribution*

WA: Coastal plain and Geraldton district, associated with *Hakea* spp.

**Remarks**

*Stanwatkinsius cinctus* is one of the smallest species. It can only be confused with *S. crassus* sp. nov. which has a similar colour combination but is one of the largest species. The structure of the male genitalia easily separates them. In *S. cinctus* the aedeagus is narrow and the parameres are slightly folded dorsally. In *S. crassus* sp. nov. the aedeagus is broad and flat.

**_Stanwatkinsius constrictus_** (Blackburn, 1897), comb. nov.
(FIG. 2h)

*Cisseis constricta* Blackburn 1887:254. Kerremans 1892:224; 1903:229. Carter 1923:167; 1929:278. Obenberger 1934:844.

*Holotype*: ♂, *Cisseis constricta* Blackburn, W. A., (I 1713) BMNH, examined.

*Other specimens examined*: WA: 2 ♀♀, Coorow, 245 km N, 16.x.38, on prickly *Hakea*, HWB, ANIC; 3 ♂♂, 2 ♀♀, Corow (sic), 17.x.1938, on prickly *Hakea*, Du Boulay collection, WAMA; 9 ♂♂, 7 ♀♀, Coorow, 17/18.x.1938, on prickly *Hakea*, H. W. Brown, MHSA; 2 ♀♀, Spencers Brook, 16.xii.1938, R.P. McMillan, WAMA; 5 ♂♂, 3, ♀♀, Wilga, 11-30.x.74, K. & E. Carnaby, ANIC; 2 ♂♂, ♀, Watning, 12.xi.50, R.P. McMillan, SAMA; ♀, Pindar, 22.ix.58, on *Casuarina*, S. Barker, SAMA; ♀, 32.09S 116.07E, Canning Reservoir, 11 km E Armidale, 8.xi.77, T. A. Weir, ANIC; 6 ♂♂, 2 ♀♀, 12.xii.1977, 3 km SW Quairading, K. Kershaw, MPWA; 2 ♂♂, Stirling Ra., 15.xi.79, D. Knowles, MPWA; ♂, 28 km S Ravensthorpe, on *A. humilis*, 22.xii.91, Golding/Powell, MPWA; ♀, 56 km NE Wubin, 18.ix.91, on *Hakea* leaves, M. Powell, MPWA; ♂, ♀, 12 km N Galena Bridge, on *A. campestris*, 30.ix.92, Golding/Powell, MPWA; ♂, Wicherina Dam, on *Grevillea* leaves, 17.i.93, Golding/Powell, MPWA; 3 ♀♀, 25 km E York, on *Hak. trifurcata*, 25.x.1997, M. Powell, MPWA; 2 ♀♀, 21.1 km SE Armidale, *Hak. trifurcata*, 14.xi.1997, Golding/Powell, MPWA; ♂, ♀, 13 km N of Galena, 11.ix.1998, T.M.S. Hanlon, MHSA; 2 ♂♂, 65 km W Watheroo, on *Hakea*, 21.x.98, M. Powell, MPWA; ♂, ♀, Swan R., Lea, SAMA.

*Male*

Size: 6.0 x 2.4 mm (33).

Colour: Head blue-green apically, purple basally. Antennomeres 1-2 blue-green; 3-11 black. Pronotum purple. Scutellum blue-green. Elytra black medially with red margin encroaching over humeral callus to basal margin. Ventral surface and legs purple with blue-green reflections.

Shape and sculpture: Head closely punctured, median sulcus at apex, short median glabrous line at base. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum striolate; apical margin projecting medially, basal margin sinuate; dorsal carina diverging from ventral carina at base, more or less parallel to ventral carina but sinuate, not reaching apical margin. Scutellum flat, without punctures. Elytra scutellate, laterally more or less parallel-sided from base, rounded post-medially and narrowed to rounded apex. Ventral surface scutellate, with short setae pointing posteriorly.

*Female*

Size: 6.1 x 2.4 mm (30).

Colour: Head coppery. Antennomeres 1-2 coppery; 3-11 black. Pronotum and scutellum coppery. Elytra black medially with a coppery margin encroaching over humeral callus to the basal margin. Ventral surface and legs coppery.

Shape and sculpture: as in male.

*Distribution*

SW WA.

### Remarks

Blackburn described *C. constricta* from Western Australia and *C. lindi* from South Australia. Carter (1923) synonymised *C. lindi* with *C. constricta*. Neither form is found in the other state and because of differences in the structure of male genitalia and colour, herein we consider them separate species. This species is closest to *S. demarzi* sp. nov. They can be distinguished on the following: *S. demarzi* is smaller than *S. cinctus*; the ventral surface of *S. cinctus* males is purple but in *S. demarzi* it is blue-green.

### *Stanwatkinsius crassus* sp. nov.
(FIG. 2e)

*Holotype*: ♂, Lake Grace, W.A., 15.xi.1971, K. & E. Carnaby, ANIC.

*Allotype*: ♀, Lake Grace, W.A., 14.xi.89, E. Sutton Collection, QMBA.

*Paratypes*: WA: ♂, 74 km W Balladonia, 21.ix.1978, T.M.S. Hanlon, on *Grevillea* flowers, WAMA; ♀, 31.11S 120.30E, 67 km WSW Coolgardie, 7.ix.1981, D.C.F. Rentz, ANIC. SA: ♂, ♀, no data, SAMA; ♀, no data, Blackburn collection, SAMA; ♂, no data, NMVA; ♀, ii.1913, NMVA.

*Male*

Size: 7.6 x 3.0 mm (5).

Colour: Head green. Antennomeres: 1-2 green; 3-11 black. Pronotum and scutellum green. Elytra black medially, purple-red laterally. Ventral surface, legs green

Shape and sculpture: Head punctured, median carina from apex to middle extending to base as impressed line; pre-medial glabrous area on each side. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum deeply striolate; anterior margin broadly projecting medially, basal margin bisinuate; dorsal carina diverging from lateral margin at base in a curve which approaches the lateral margin post-medially but does not reach it. Scutellum flat, without punctures, anterior margin concave. Elytra shallowly punctate medially, scutellate laterally; laterally more or less parallel-sided until rounded post-medially and then narrowed to rounded apices. Ventral surface striolate with sparse short setae.

*Female*

Size: 7.9 x 3.3 mm (4).

Colour: Head purple apically, green basally. Antennomeres: 1 purple; 2-11 black. Pronotum dull green. Scutellum black. Elytra black medially, purple-red laterally. Ventral sterna purple with green reflections; abdomen green except for S7 purple. Legs purple.

Shape and sculpture: as in male.

*Distribution*

WA: Lake Grace, Balladonia. SA: no locality data available. One specimen collected on *Grevillea*.

### Remarks

The colour combination of this species is similar to that found in *S. cinctus*. Their distinguishing features are discussed earlier.

*Etymology*

This species is named for its shape *crassus* L., broad.

### *Stanwatkinsius demarzi* sp. nov.
(FIG. 2m)

*Holotype*: ♂, Woodridge, W.A., intercept trap, 9.xi.1997, H. Demarz, SAMA I 21493.

*Allotype*: ♀, Woodridge, W.A., intercept trap, 10.xi.1998, H. Demarz, SAMA I 21494.

*Paratypes*: WA: ♂, ♀, Woodridge, 20.x.96, H. Demarz, SAMA; ♂, ♀, 4.xi.96, Woodridge, intercept trap, H. Demarz, SAMA; ♂, 7.xi.96, Woodridge, intercept trap, H. Demarz, SAMA; ♂, 10.xi.96, Woodridge, intercept trap, H. Demarz, SAMA; 2 ♂♂, Woodridge, intercept trap, 1/18.xi.1997, H. Demarz, SAMA; 2 ♂♂, Woodridge, intercept trap, H. Demarz, 30.x.1998 SAMA; ♂, Woodridge, intercept trap, 18.xi.1998, H. Demarz, CLBC & SAMA; ♂, Woodridge, intercept trap, 3.xii.1998, H. Demarz, HDWA.

*Male*

Size: 5.5 x 2.2 mm (11).

Colour: Head green with yellow reflections apically, blue-green basally. Antennomeres: 1 blue-green; 2-11 black. Pronotum and scutellum blue-green. Elytra dark brown medially with red margin encroaching over humeral callus to basal margin. Ventral surface and legs blue-green.

Shape and sculpture: Head finely punctured, small median apical sulcus. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum striolate; apical margin projecting medially, basal margin sinuate; dorsal carina diverging from ventral carina basally then parallel to it, not reaching margin. Scutellum scutiform, flat, wrinkled. Elytra scutellate; laterally more or less straight-sided from base, sides gradually converging, rounded post-medially and narrowed to rounded apices. Ventral surface scutellate with sparse very short setae pointing posteriorly

*Female*

Size: 5.4 x 2.3 mm (3).

Colour: Head, pronotum and scutellum coppery. Elytra as in male. Ventral surface and legs coppery.

Shape and sculpture: as in male.

*Distribution*

*Banksia menziesii* R. Br. woodland on WA coastal plain.

## Remarks

This species is closest to *S. constrictus*. Their distinguishing features have been discussed previously.

*Etymology*

Named after the collector H. Demarz, Woodridge, WA

## *Stanwatkinsius grevilleae* sp. nov.
(FIG. 2k)

*Holotype*: ♂, 13 km N Galena, WA, 11.ix.1998, T. M. S. Hanlon, SAMA I 21495.

*Allotype*: ♀, same data as holotype, SAMA I 21503

*Paratypes*: WA: 3 ♀♀, Tammin, 28.ix.1936, on *Hakea*, H. W. Brown, MHSA; ♀, Burracoppin, 8.x.1938, on *Hakea*, H. W. Brown, MHSA; 6 ♂♂ 7 ♀♀, Cuntow, 16/17.x.1938, on *Hakea*, H. W. Brown, MHSA; ♂, Spencer's Brook, 16.x.45, R. P. McMillan, SAMA; 2 ♂♂, Yellowdine, 11.x.53, F. H. Uther Baker, WAMA; ♀, Lake Varley, 21.ix.54, F. H. Uther Baker, WAMA; ♂, 34 km E Yellowdine, 16.x.77, M. Peterson, MPWA; ♂, no 7 tank, x.1977, M. Powell, MPWA; ♀, N7T Radio, 12.x.77, M. Powell, MPWA; 3 ♂♂, N7T Radio, 13.x.77, M. Powell; 2 ♀♀, 34 km E Yellowdine, 13.x.77 S. Wilson, MPWA; ♀, Carrabin, 13.x.1980, on *Melaleuca*, T. M. S. Hanlon, MHSA; 2 ♂♂, 9 km NNE Zanthus, on *Grevillea* leaves, 21.x.86, M. Powell, MPWA; ♀, 10 km E Norseman, 24.x.86, on *Casuarina*, M. Powell, MPWA; ♂, 10 km SW Moir Rock, 18.xi.88, on *Grevillea* leaves, M. Powell, MPWA; 3 ♂♂, ♀, 34 km E Yellowdine, 28.x.89, on *Grevillea* leaves, Golding/Powell, MPWA; ♂, 19 km N Galena, 22.ix.90, on *Casuarina*, Golding/Powell, MPWA; ♀, N7T, 32 km E Yellowdine, 21.x.1991, on *Casuarina*, T. M. S. Hanlon, MHSA; ♀, 60 km N Galena Bridge, 28.ix.92, on *Grevillea* fol., Golding/Powell, MPWA; ♂, 12 km N Galena Bridge, 30.ix.92, on *A. campestris*, Golding/Powell, MPWA; 3 ♂♂, 3 ♀♀, 49 km N Galena Bridge, 10.x.92, Golding/Powell, MPWA; ♀, 53 km E Yellowdine, 23.x.93, *Casuarina*, M. G./M. P., MPWA; ♂, 2 ♀♀, 15 km S Billabong, 20.x.1996, Kershaw/Golding, MGWA; ♂, 48 km N Galena Bridge, 7.ix.1996, on *Grevillea*, Golding/Powell, MPWA; 2 ♂♂, 5 ♀♀, 80 km N Moora, 20.x.1996, *Allo. campestris*, D. Knowles, MPWA; 4 ♂♂, 4 ♀♀ 73 km ENE Kumarina, 27.viii.1997, on *Grevillea* leaves, D. Knowles, MPWA; ♂, 5 ♀♀, same data as holotype, MHSA; 2 ♂♂, 2 ♀♀, 40 km N Koolyanobbing, 9.x.98, on *Grevillea*, M. Powell, MPWA; ♂, 3 ♀♀, 40 km N Koolyanobbing, 9.x.1998, *Grevillea* leaves, T. M. S. Hanlon, MHSA; 3 ♂♂, 4 ♀♀, 92 km W Useless Loop, 15.x.1999, on *Grevillea* leaves, S. Barker, SAMA;

*Male*

Size: 6.2 x 2.4 mm (41).

Colour: Head blue-green, coppery on the apical margin between the antennal foveae. Pronotum blue green sometimes with medial yellow reflections. Scutellum blue-green with variable yellow reflections. Elytra dark brown with red lateral margins continuous for short distance along basal margin. Ventral surface and legs blue-green

Shape and sculpture: Head coarsely punctured, median apical fovea. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum striolate, apical margin straight, basal margin sinuate, dorsal carina diverging from ventral carina at base then more or less parallel-sided until terminating before reaching the anterior margin. Scutellum flat, without punctures. Elytra scutellate, laterally parallel-sided from base, rounded post-medially and narrowed to rounded apices. Ventral surface scutellate with short setae.

*Female*

Size: 6.5 x 2.5 mm (49).

Colour: Head, pronotum scutellum, ventral surface and legs rose-red. Elytra dark brown with rose-red lateral margin extending for short distance along basal margin.

Shape and sculpture: as in male.

*Distribution*

SE and SW WA, associated with *Grevillea* spp.

**Remarks**

This species is closest to *S. demarzi* sp. nov. They can be separated on the following: *S. grevilleae* is larger, 6.2 mm against 5.5 mm, and does not occur on the coastal plain; in males, the margin dorsad to the antennal fovea is cupreous, but is not in *S. demarzi*; the head punctation is noticeably coarser in *S. grevilleae* than in *S. demarzi*

*Etymology*

The species is named for its association with *Grevillea* spp.

***Stanwatkinsius kermeti*** sp. nov.
(FIG. 2g)

*Holotype*: ♂, Boyne R., 120 km S Rockhampton, Qld, 4.xi.1975, on *Casuarina cunninghamiana*, S. Barker, SAMA I 21496.

*Paratypes*: Qld: 2 ♂♂, Gladstone, 20.xii.45, S. Brock, ANIC. NSW: ♂, Charity ck. Bridge, Manning R. via Kimbricki, 10.xii.91, S. Watkins, SAMA.

*Male*

Size: 6.9 x 2.4 mm (4).

Colour: Head, antennae, pronotum, scutellum green with yellow reflections. Ventral surface green. Legs green with yellow reflections

Shape and sculpture: Head punctured, flat, with thin glabrous median line from apex to middle, continuing to base as impressed line, with a round glabrous patch on each side closer to apex than base. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum striolate; anterior margin projecting medially, basal margin bisinuate; lateral carina diverging from lateral margin basally, then more or less parallel to it until after middle where it terminates. Scutellum flat, without punctures, anterior margin convex. Elytra with shallow punctures medially, striolate laterally; margin parallel sided from base until post-medial, tapered to rounded apices. Ventral surface faintly scutellate, with sparse short setae.

*Female*

Unknown

*Distribution*

Qld: Gladstone, on *Casuarina cunninghamiana* Miq. NSW: Northern coastal, on *Casuarina cunninghamiana*.

**Remarks**

This is an elongate species. It differs from all but *S. powelli* sp. nov. in the position of the dorsal carina on the pronotum. Viewed from above, the sides of the pronotum diverge from the base; they converge to the apical margin at the point where the dorsal carina converges on the ventral carina, forming a slight protuberance on each side. Male genitalia are a different shape from males of *S. uniformis* the only other all green, but smaller species.

*Etymology*

The species is named after Kermet the green frog from the Muppets.

***Stanwatkinsius lindi*** (Blackburn, 1897), comb. nov
(FIG. 2i)

*Cisseis lindi* Blackburn 1887:254; 1891:300. Kerremans 1892:225; 1903:229. Carter 1923:167; 1929:278. Obenberger 1934:844.

*Holotype*: ♂, *Cisseis lindi* Blackburn, S.A., (T 319) BMNH, examined.

*Other specimens examined*: SA: 4 ♂♂, 2 ♀♀ Tanunda, 1.xi.1887, Tepper, SAMA; ♀, Williamstown, 22.x.1888, Tepper, SAMA; 2 ♂♂, 2 ♀♀, Lucindale, Feuerheerdt, SAMA; 2 ♂♂, Warunda, Eyre Peninsula, x.1909, S.A. White, SAMA; ♀, ii.13, NMVA; ♂, ♀, no data, QMBA; ♂, no data, SAMA; ♂, 18km W Vivonne Bay, Kangaroo Island, 12.x.1966, N. McFarland, M. Pate, SAMA; 2 ♂♂, Verran Hill, Hincks N.P., Eyre Peninsula, 7.x.1979, D. Lacis, SAMA. Vic.: ♀, Little Desert, 11 km S Kiata, 9.xi.1978, S. Barker, SAMA; ♀, Big Desert, 12 km N Broken Bucket well, 16.xi.1981, S. Barker, SAMA.

*Male*

Size: 5.9 x 2.4 mm (11).

Colour: Head coppery. Antennomeres: 1 coppery; 2-11 black. Pronotum and scutellum coppery or coppery bronze. Elytra dark blue medially, red laterally. Ventral surface and legs coppery.

Shape and sculpture: Head with close, shallow punctures, shallow median sulcus at apex soon projecting into an impressed line reaching base. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum striolate, apical margin projecting medially over half its length, basal margin bisinuate, dorsal carina convex, widely separated from ventral carina except at base, not reaching apical margin, interval between wrinkled. Scutellum flat, glabrous, basal margin slightly concave. Elytra punctured medially, scutellate laterally, margin parallel-sided from base, rounded post-medially and narrowed to rounded apex. Ventral surface scutellate, with moderately long setae.

*Female*

Size: 6.0 x 2.5 mm (10).

Colour: as in male.

Shape and sculpture: as in male.

*Distribution*

SA: Barossa Valley, SE, Kangaroo I. Vic.: Big and Little Deserts.

### Remarks

The only species known to overlap the distribution of *S. lindi* is *S. uniformis*, a small all green species. Differences between *S. lindi* and *S. constrictus* are discussed earlier.

### *Stanwatkinsius macmillani* sp. nov. (FIG. 2f)

*Holotype*: ♂, Watning, W.A., 19.xi.1950, R. P. McMillan, SAMA I 21497.

*Paratypes*: 4 ♂♂, same data as holotype, SAMA; 3 ♂♂, Bejoording, W.A., 19.xi.1950, R. P. McMillan, WAMA

*Male*

Size: 6.0 x 2.2 mm (8).

Colour: Head green apically with yellow reflections, blue-green basally. Antennomeres: 1-2 green; 3-11 black. Pronotum and scutellum blue-green. Elytra brown medially green laterally. Ventral surface and legs blue-green.

Shape and sculpture: Head punctured, very small sulcus at apex projecting post-medially as impressed line. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum striolate; apical margin more or less straight, basal margin bisinuate; dorsal carina diverging from ventral carina at basal margin then more or less parallel-sided, convex post-medially but not reaching apical margin or ventral carina. Scutellum flat, without punctures. Elytra scutellate; laterally more or less parallel-sided from base, rounded post-medially and narrowed to rounded apices. Ventral surface scutellate with short setae.

*Female*

Unknown.

*Distribution*

Known only from two localities in WA, both devastated by land clearance for agriculture.

### Remarks

This species is closest to *S. demarzi* sp. nov. They can be separated on the following: the male genitalia are a different structure; their colour patterns are different.

*Etymology*

Named after the collector, R. P. McMillan, Kallaroo.

### *Stanwatkinsius powelli* sp. nov. (FIG. 2e)

*Holotype*: ♂, 74 km SE Yalgoo, W.A., 19.9.91, on *Grevillea* leaves, M. Powell, SAMA I 21498.

*Allotype*: ♀, same data as holotype, SAMA I 21499.

*Paratypes*: WA: ♂ same data as holotype, MPWA; ♂, ♀, Cue, H. W. Brown, MHSA.

*Male*

Size: 6.2 x 2.2 mm (3).

Colour: Head green or purple with cupreous reflections. Antennae bronze. Pronotum green or purple medially, cupreous laterally. Scutellum cupreous. Elytra purple medially, merging into a very narrow violet band which abuts lateral bronze mark anteriorly and lateral blue mark apically. Ventral surface and legs purple with cupreous reflections.

Shape and sculpture: Head shallowly punctured, with medial carina at apex projecting to base as impressed line, with a protuberance on each side closer to base than apex. Antennomeres: 1-4 obconic; 5-11 triangular. Pronotum striolate; apical margin projecting medially, basal margin sinuate; dorsal carina diverging from ventral carina at base, convex reaching ventral carina post-medially. Scutellum flat, without punctures. Elytra scutellate, laterally more or less parallel-sided, round post-medially and narrowed to rounded apices. Ventral surface scutellate, with short setae.

*Female*

Size: 6.7 x 2.4 mm (2).

Colour: as in male.

Shape and sculpture: as in male.

*Distribution*

The specimens were collected from two localities in WA. Those from Cue had green heads, those from near Yalgoo had purple heads.

### Remarks

The dorsal carina on the pronotum is positioned in the same way as in *S. kermeti* sp. nov. as previously discussed. That feature and the colour pattern distinguishes the species from all others.

*Etymology*
Named after M. Powell, Melville.

### *Stanwatkinsius rhodopus* sp. nov.
(FIG. 2d)

*Holotype*: ♀, Marsupial Ck E Croydon, NQld, 26.iv.1996, J. & P. Hasenpusch. SAMA I 21492.

*Male*
Unknown.

*Female*
Size: 8 x 3 mm (1).
Colour: Head roseate. Antennomeres: 1-2 cupreous; 3-11 black. Pronotum black medial band, roseate laterally. Scutellum mainly black, cupreous at ends of lateral extensions. Elytra dark blue along suture and at apex, green-blue laterally. Ventral surface and legs cupreous purple.

Shape and sculpture: Head punctured, small median carina at apex located in a depression with a glabrous unpunctured area on each side, continuing to base as impressed line. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum punctured medially, striolate laterally; anterior margin projecting medially, basal margin bisinuate; dorsal carina diverging sinuously from lateral margin basally approaching lateral margin post-medially but not reaching it. Scutellum flat, without punctures, basal margin straight. Elytra punctured medially, scutellate laterally; margin parallel-sided from base rounded post-medially and narrowed to rounded apices. Ventral surface shallowly punctured medially, scutellate laterally with very short setae.

*Distribution*
This species is known from a single locality in N Qld

### Remarks

This species occurs further north than any other known species.

Because of its unique colouration it cannot be confused with any other species.

*Etymology*
The species is named for its rose coloured head and pronotum from *rhodopus*, Gk rosy.

### *Stanwatkinsius speciosus* sp. nov.

(FIG. 2f)

*Holotype*: ♂, 25 km N Eneabba, W.A., 24/25.x.1984, at night, A. A. Calder, ANIC.

*Allotype*: ♀, same data as holotype, ANIC.

*Paratypes*: WA; ♀, no data, Blackburn, SAMA: ♀, 17 km S Northampton, 1.x.1981, I. D. Naumann, J. C. Cardale, ANIC.

*Male*
Size: Male, 6.6 x 2.7 mm (1).
Colour: Head green apically, violet basally. Antennomeres: 1-2 green; 3-11 bronze. Pronotum violet laterally brassy-bronze medially. Scutellum violet. Elytra brassy bronze laterally, bronze medially. Ventral surface and legs violet.

Shape and sculpture: Head punctured, shallow median sulcus apically, merging into impressed line reaching base. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum striolate, apical margin broadly projecting medially, basal margin bisinuate; dorsal carina diverging from lateral margin basally then more or less parallel-sided until post-medial, not reaching apical margin. Scutellum flat, without punctures, basal margin concave. Elytra punctured medially, scutellate laterally; lateral margins more or less parallel-sided from base until rounded post-medially then narrowed to rounded apices. Ventral surface scutellate, with short setae.

*Female*
Size: 6.7 x 2.6 mm (3).
Colour: entirely coppery-red.
Shape and sculpture: as in male.

*Distribution*
WA: Coastal plain between Eneabba and Northampton associated with *Hakea* spp.

### Remarks

This species is closest to *S. constrictus*. It can be distinguished by: being larger species than *S. constrictus*; male genitalia are broader than in *S. constrictus*; the colour pattern of males and females of both species is different.

*Etymology*
This species is named for its colour *speciosus* L., beauty.

**_Stanwatkinsius subcarinifrons_** (Thomson, 1879), comb. nov.
(FIG. 2p)

*Cisseis subcarinifrons* Thomson 1879:53. Kerremans 1892:227 (*subcarenifrons*); 1903:230 (*subcarenifrons*). Carter 1923:167 (*subcarenifrons*); 1929:279 (*subcarenifrons*). Obenberger 1934:855 (*subcarenifrons*).

*Cisseis occidentalis* Blackburn 1887: 255. Kerremans 1892:226; 1903:230. Carter 1923:167 (? var. *subcarenifrons*); 1929:279. Obenberger 1934:851. syn. nov.

*Holotype*: ♀, *C. subcarinifrons* Thomson, King George's Sound, MNHN, examined. Holotype ♂, *C. occidentalis* Blackburn, Western Australia, BMNH examined.

*Other specimens examined*: WA: 11 ♂♂, 3 ♀♀, 9.6 km W Goomalling, 2.xii.56, S. Barker, SAMA; 2 ♂♂, ♀, 6.4 km E Bejoording, 2.xii.56, S. Barker, SAMA; 4 ♂♂, 109 km N Geraldton Hway, 1.xii.1956, S. Barker, SAMA; ♂, ♀, 3 km NE Gosnells, 1.xii.1957, S. Barker, SAMA; ♀, 13 km E North Bannister, 19.xi.1970, S. Barker, SAMA; ♀, 58 km W Tammin, Goldfields Rd., 23.xii.1972, S. Barker, SAMA; ♂, ♀, Woodridge, intercept trap, 7.xi.1997, H. Demarz, CLBC; ♀, Woodridge, 8.xii.1997, H. Demarz, SAMA; ♀, Woodridge, 18.xi.1998, H. Demarz, SAMA; 3 ♀♀, Woodridge, 3.xii.1998, H. Demarz, HDWA; ♂, Swan R., Lea, SAMA.

*Male*

Size: 5.9 x 2.3 mm (19).

Colour: Head brown or green. Pronotum brown medially, green laterally. Scutellum brown. Elytra usually brown, some specimens green laterally. Ventral surface and legs green.

Shape and sculpture: Head punctured, with short median carina from apex continuing to base as impressed line. Antennomeres: 1-4 obconic; 5-11 triangular. Pronotum striolate; anterior margin broadly projecting medially, basal margin bisinuate; dorsal carina diverging from lateral margin basally, curving towards lateral margin post-medially but not reaching it. Scutellum flat, without punctures, anterior margin straight. Elytra scutellate, faintly medially, heavily laterally; laterally parallel-sided until rounded post-medially, then narrowed to rounded apices. Ventral surface scutellate, with short setae.

*Female*

Size: 6.2 x 2.4 mm (10).

Colour: as in male

Shape and sculpture: as in male.

*Distribution*

SW WA, associated with *Allocasuarina* spp.

**Remarks**

This species is one of the smallest in the genus. Its colour combination is unique and it cannot be confused with any other species.

**_Stanwatkinsius uniformis_** (Thomson, 1879), comb. nov.
(FIG. 2n)

*Cisseis uniformis* Thomson 1879:53. Kerremans 1892:227; 1903:230. Carter 1923:167; 1929:279. Obenberger 1934:856.

*Cisseis coraeboides* Kerremans 1898:166; 1903:229. Carter 1923:167 (syn. *uniformis*); 1929:279, Obenberger 1934:856.

*Holotype*: MNHN, not examined. 4 ♂♂ syntypes *Cisseis coraeboides* Kerremans, BMNH, examined.

*Other specimens examined*: SA: 2 ♂♂, Nuriootpa, J. G. O. Tepper, SAMA; ♂, ♀, Ardrossan, J. G. O. Tepper, SAMA; ♀, York Peninsula, Jung, SAMA; ♂, Adelaide Hills, *Casuarina stricta*, 29.xi.64, S. Barker, SAMA; 3 ♂♂, 3 ♀♀, Monarto South, 2.xi.1967, S. Barker, SAMA; 4 ♂♂, ♀, Summit Mt Barker, 16.xii.1967, S. Barker, SAMA; 2♂♂, 6 ♀♀, Sellicks Scrub, 24.xi.1979, S. Barker, CLBC & SAMA. Vic.: ♀, Monbulk, Jarvis, SAMA.

*Male*

Size: 5.5 x 2.2 mm (13).

Colour: Most specimens entirely green. A few with bronze pronotum, very few with green head, bronze on the dorsal surface and green-bronze on ventral surface and legs.

Shape and sculpture: Head punctured, flat, thin median glabrous line from apex to premedial continuing to apex as impressed line. Antennomeres: 1-4 obconic; 5-11 triangular. Pronotum striolate; apical margin straight, basal margin bisinuate; dorsal carina diverging from lateral margin at base not continued past middle. Scutellum flat, rough without punctures. Elytra striolate; laterally parallel-sided from base rounded post-medially and tapered to rounded apex. Ventral surface striolate, with short setae.

*Female*

Size: 6.0 x 2.3 mm (13).

Colour: as in male.

Shape and sculpture: as in male.

*Distribution*

SA and Vic., associated with *Allocasuarina verticillata* (Lam.).

### Remarks

This is one of the smallest species in the genus. The only other all green species is the larger *S. kermeti* sp. nov. They differ in the position of the dorsal carina on the pronotum, visible when viewed from above in *S. kermeti* but not in *S. uniformis*.

### *Stanwatkinsius viridimarginalis* sp. nov. (FIG. 2j)

*Holotype*: ♂, 34 km E Yellowdine, W.A., 16.x.1977, M. Peterson, SAMA I 21501.

*Allotype*: ♀, same data as holotype, SAMA I 21502.

*Paratypes*: WA: ♂, Dryandra State Forest c. 27 km NW of Narrogin, 3.x.1982, C. A. Howard & T. F. Houston, WAMA; ♀, Durokoppin Nature Reserve, 25 km N of Kellerberrin, 22-24.xi.1996, T. F. Houston, WAMA; ♂, Swan R., Lea, SAMA.

*Male*

Size: 6.5 x 2.5 mm (3).

Colour: Head and antennae green. Pronotum dull purple medially, bright green laterally. Scutellum green medially purple laterally. Elytra dark purple medially merging into a narrow coppery band laterally which abuts a bright green lateral margin. Ventral surface and legs green.

Shape and sculpture: head closely punctured without setae. Antennomeres: 1-4 obconic; 5-11 triangular. Pronotum striolate; apical margin projecting medially, basal margin bisinuate; dorsal carina diverging from ventral carina at base then more or less parallel to it until postmedial, not reaching apical margin. Scutellum flat, without punctures. Elytra scutellate, laterally parallel-sided from base, rounded post-medially and narrowed to rounded apices. Ventral surface scutellate with sparse short setae in male, dense longer setae in female.

*Female*

Size: 8.2 x 3.2 mm (2).

Colour: head and antennae dark purple with coppery reflections. Scutellum and elytra as in male. Ventral surface and legs coppery.

Shape and sculpture: as in male except head setose.

*Distribution*

This species is only known from Yellowdine, Narrogin and Kellerberrin districts, all in WA.

### Remarks

This is an elongate species. Its colour combination makes it distinct from all other species.

*Etymology*

Named for the lateral green stripe around the elytra *viridis* L., green, *margino* L., furnish with a border

## Discussion

Species of *Stanwatkinsius*, although similar in general appearance to several groups of Australian buprestids, are true coraebines and thus likely to have diverged from the lineage that also gave rise to *Cisseis* and its relatives. The similarity in ovipositor morphology to *Meliboeithon* is likely less diagnostic of common descent than of the fluidity of these organs in response to oviposition requirements from specific plant associations and placement of eggs on the host, e.g. above or below the substrate. From the phylogenetic perspective suggested by Bellamy (1988), and subsequent discussion with colleagues about coraebine evolution, it would seem that the use of ovipositor morphology as an indicator of evolutionary divergence is perhaps not well-founded since in some genera, e.g. *Coraebus* Gory & LaPorte, there is a wide range of ovipositor morphology, both in the so-called general buprestid form and in the 'coraebine' ovipositor which possess ventral brushes. However, in the Australian coraebine genera studied by the authors, either one type or the other is present. Since *Stanwatkinsius* is obviously related to but divergent from the *Cisseis* lineage, the different ovipositor would split the former genus to the opposite side of the suggested phylogeny (Bellamy 1988) from *Cisseis* and its relatives such as *Neospades* Blackburn, *Alcinous* Kerremans and *Pachycisseis* Théry. Pending the completion of a revision of *Cisseis*, there is no reason to venture into further phylogenetic speculation at this time.

## Acknowledgments

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# NEW SPECIES OF OTIONELLINA AND SELENARIA (BRYOZOA-CHEILOSTOMATA) FROM THE SOUTH WEST SHELF, WESTERN AUSTRALIA

*By T. J. Conroy*, P. L. Cook† & P. E. Bock†*

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Key Words: Otionellina boneae sp. nov., Selenaria kayae sp. nov., Selenaria meganae sp. nov., new species, lunulite bryozoans, South West Shelf, Western Australia.

*Transactions of the Royal Society of S. Aust.* (2001), **125**(1), 15-23.

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KEY WORDS: *Otionellina boneae* sp. nov., *Selenaria kayae* sp. nov., *Selenaria meganae* sp. nov., new species, lunulite bryozoans, South West Shelf, Western Australia.

## Introduction

The mid-latitude continental margin of Western Australia represents a transition from cool-water carbonate production to warm-water tropical carbonate production (Fig. 1)(Conroy 1996[1]). This paper provides the first documentation of the nature, density and distribution of Recent lunulite bryozoans on the SWS. Despite extensive research on the Leeuwin Current, the bottom sediments of the wave-dominated, open continental shelf are relatively unreported upon.

Detailed analysis of the sediments collected by a scientific team aboard the RV *Franklin* in 1996 has revealed the presence of 12 species of lunulite bryozoans, three of which are hitherto undescribed. These bryozoans include two species of *Helixotionella*, *H. spiralis* (Chapman 1913) and *H. scutata* (Cook & Chimonides 1984b), three of *Otionellina*, *O. australis* (Cook & Chimonides 1985b), *O. nitida* Maplestone, 1909 and *O. boneae* sp. nov., five of *Selenaria*, *S. maculata* (B) (Busk 1852b), *S. punctata* (Tenison-Woods 1880), *S. varians* (Cook & Chimonides 1987), *S. kayae* sp. nov. and *S. meganae* sp. nov. and two of *Lunularia*, *L. capulus* (Busk 1852a) and *L. repanda* (Maplestone 1904) (Table 1).

Lunulite bryozoans may be locally abundant and live upon or within the upper layers of the bottom sediments, supported and stabilised by the extended mandibles of the peripheral and subperipheral avicularia. The avicularian morphology of *O. boneae* sp. nov. makes it unlikely that it is capable of colony locomotion like that of *O. symmetrica* (Cook & Chimonides 1984a), the only species of this genus which has been observed alive. The colonies of *S. kayae* sp. nov. and *S. meganae* sp. nov. have no avicularian mandibles preserved but their skeletal morphology suggests that they had the capacity for locomotion, as in all observed species of *Selenaria*. Observations on living material of the three new species would assist in the understanding of the correlation between skeletal and mandibular morphology and avicularian function.

## Materials and Methods

Abbreviations of institutions which are repositories of the specimens referred to in this paper are: South Australian Museum, Adelaide (SAMA), Department of Geology and Geophysics, University of Adelaide (UA), Museum Victoria, Melbourne (MU), British Museum (Natural History), London (BMNH).

Sediment samples were collected by towing an epibenthic sled along the sea floor at a speed of two knots for three to five minutes. This provided a mixed sample of surface and subsurface material

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[1] CONROY, T (1996) Vagrant Bryozoans from the South West Shelf, W.A.: Their distribution, taxonomy, geochemical characteristics and relevance to palaeoecological studies. BSc (Hons) Thesis, University of Adelaide (unpub.).

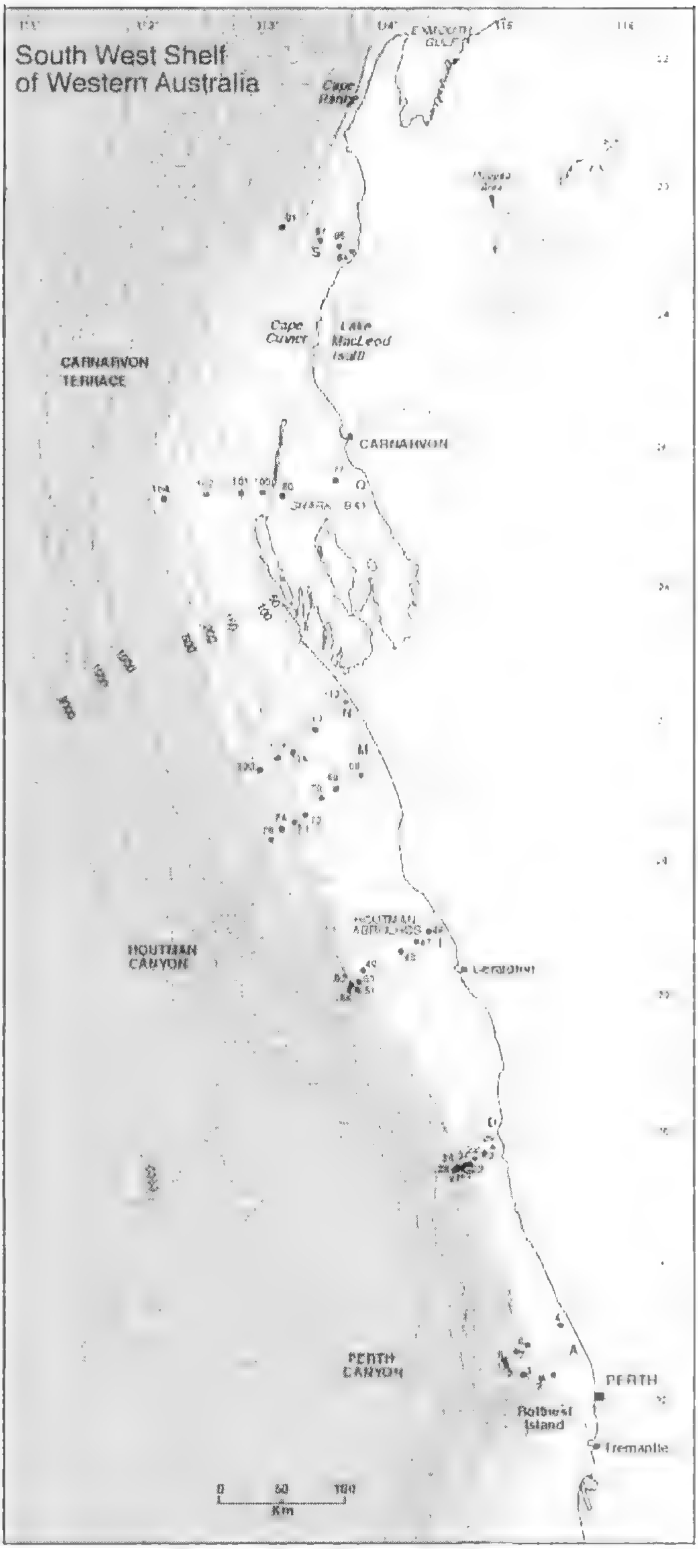


Fig. 1. Map of the South West Shelf, Western Australia showing transects, location sites and bathymetry.

TABLE 1. *Species counts from the SWS.*

| Species | Living specimens | Non - living specimens | Total |
|---|---|---|---|
| *H. scutata* | 52 | 916 | 968 |
| *H. spiralis* | 5 | 209 | 214 |
| *L. capulus* | 33 | 86 | 119 |
| *L. repanda* | 0 | 10 | 10 |
| *O. australis* | 3 | 139 | 142 |
| *O. nitida* | 3 | 103 | 106 |
| *O. boneae* sp. nov. | 9 | 63 | 72 |
| *S. maculata* | 313 | 772 | 1085 |
| *S. punctata* | 12 | 1924 | 1936 |
| *S. varians* | 2 | 399 | 401 |
| *S. kayae* sp. nov. | 0 | 196 | 196 |
| *S. meganae* sp. nov. | 0 | 256 | 256 |

from a depth of approximately 100 - 150 mm. The sampling was conducted along transects across the continental shelf, shelf edge, slope and abyssal plain of the SWS between 23° and 32° S and from depths ranging from 39 - 314 m (Tables 2, 3). Measurements of *Otionellina* and *Selenaria* species are recorded in Table 4.

Sea floor sediment samples range from 0.4 kg to 2 kg in weight. Recorded lunulite bryozoan numbers are the total number of lunulite bryozoans present in the available sediment samples.

Specimens were cleaned ultrasonically in a 1:50 solution of commercial strength bleach and water before being rinsed in deionised water, dried and coated with a gold-palladium mixture for scanning electron microscopy (SEM).

*Identification of colonies*

Many of the colonies, preserved within the fine-grained sea-bottom sediments where they had lived and died, were relatively undamaged and included cuticular structures such as opercula and avicularian mandibles intact. Even if these were absent, the skeletal structure was complete. The amount of wear and breakage depends both on the nature of the sediment and the initial robustness of the species. *Otionellina boneae* sp. nov. colonies are up to 5 mm in diameter and are heavily calcified and flat basally. They are so robust that they are generally found as whole colonies with undamaged zooids and so the species are readily identified. Colonies of *Selenaria kayae* sp. nov. are also basally thickened with flattened margins at the periphery of sexually mature colonies formed by calcified kenozooids; this helps to preserve them in their entirety. In contrast, colonies of *S. meganae* sp. nov are flat and thinly calcified basally and are generally fragile. This species is difficult to distinguish from others unless its colonies are sexually mature and have an undamaged ancestrular region.

## Systematics

Order Cheilostomatida Busk, 1852
Family Otionellidae Bock & Cook, 1998
Genus *Otionellina* Bock & Cook, 1998
Type species: *Otionella australis* Cook & Chimonides, 1985

Colonies budded radially from an ancestrula which has one distal and one proximal adjacent avicularium. Basal surface flat or concave, formed by sectors of porous extrazooidal calcification. Autozooids with small rounded or oval opesia and well-developed cryptocyst. Brooding zooids marginal with an enlarged opesia; skeletally distinct male zooids unknown. Avicularia smaller than autozooids, with paired condyles, which may be fused in some species; opesia symmetrical or asymmetrical, open, or closed by a porous cryptocyst lamina. Mandibles spoon-shaped, or more elongated, with two expansions and serrate margins. Note that Bock & Cook (1998) separated this genus from *Otionella* devised by Canu & Bassler (1917).

### *Otionellina boneae* sp. nov.
(FIGS 2-4 )

*Material examined*

*Holotype*: Sample 85B, Transect S, 23° 26.57' S, 113° 45.22' E, 50 m, 21.i.1996, SAMA, SAM L894
*Paratypes*: Sample 85B, Transect S, 23° 26.57' S, 113° 45.22' E, 50 m, 21.i.1996, SAMA, SAM L895.
*Other material*: Sample 101B, Transect Q, 25° 18.29' S, 112° 48.36' E, 100 m, 23.i.1996, MV, F86428; Sample 102B, Transect Q, 25° 18.01' S, 112° 33.97' E, 121.1 m, 23.i.1996, MV, F86429; Sample 102B, Transect Q, 25° 18.01' S, 112° 33.97' E, 121.1 m, 23.i.1996, BMNH, 1999.11.18.1; Sample 102B, Transect Q, 25° 18.01' S, 112° 33.97' E, 121.1 m, 23.i.1996, UA.

*Description*

Colonies bun-shaped, solid basally, with a few irregular sector boundaries and small pores; sexually mature with peripheral brooding zooids by the fifth to eighth astogenetic generations. Autozooids with

Fig. 2. *Otionella boneae* sp. nov. Mandible. Scale bar = 0.50 mm.

TABLE 2. *Ecological ranges of species from the SWS.*

| Species | Transects | Depth in m. | Bottom temp.° C | Salinity, ‰ |
|---|---|---|---|---|
| *H. scutata* | A,D,I,M,Q,S | 77.1-221 | 18.8-22.8 | 35-35.8 |
| *H. spiralis* | A,D,I,M,N | 139-221 | 17.3-19.7 | 35.7-35.8 |
| *L. capulus* | A,D,M,N | 39-139 | 18.9-22.2 | 35.7-35.8 |
| *L. repanda* | A,D | 97-158 | 18.9-19 | 35-35.8 |
| *O. australis* | A,D,I,M,Q,S | 50-221 | 18.8-24 | 35.2-35.8 |
| *O. nitida* | N,Q,S | 50-100 | 22.8-24 | 35.2-35.36 |
| *O. boneae* sp. nov. | A,N,Q,S | 50-121 | 22.3-22.5 | 35-35.4 |
| *S. maculata* | A,D,M,N,Q,S | 50-221 | 18.8-24 | 35-35.8 |
| *S. meganae* sp. nov. | D,M,N,Q,S | 50-170 | 18.8-24 | 35-36 |
| *S. punctata* | A,D,I,M,N,Q,S | 44-203 | 17.3-22.8 | 35.2-35.8 |
| *S. kayae* sp. nov. | A,D,M,N,Q | 66-221 | 18.9-23 | 35.4-36 |
| *S. varians* | A,D,M,Q,S | 66-158 | 18.9-23 | 35-36 |

TABLE 3. *Details of transects.*

| Line | Location | Starting latitude and longitude of transect | Finishing latitude and longitude of transect |
|---|---|---|---|
| A | NW of Perth | 31°45.21′ S, 115°24.17′ E | 31°43.36′ S, 115°00.47′ E |
| D | Off Green Head | 30°09.47′ S, 114°53.50′ E | 30°20.31′ S, 114°35.57′ E |
| I | NW of Geraldton | 28°32.14′ S, 114°21.90′ E | 28°52.42′ S, 113°43.50′ E |
| M | NW of Bluff Point | 27°27.21′ S, 113°57.94′ E | 27°50.18′ S, 113°06.13′ E |
| N | S of Zuytdorp Cliffs | 26°54.45′ S, 113°42.33′ E | 23°18.18′ S, 113°08.65′ E |
| Q | N of Shark Bay | 25°11.52′ S, 113°35.12′ E | 24°42.00′ S, 113°23.00′ E |
| S | Cape Farquhar | 23°28.89′ S, 113°37.02′ E | 23°17.11′ S, 113°02.71′ E |

TABLE 4. *Measurements in mm of species of* Otionellina *and* Selenaria *described here.*

| | *Otionellina boneae* sp. nov. | *Selenaria kayae* sp. nov. | *Selenaria meganae* sp. nov. |
|---|---|---|---|
| Lan | 0.46-0.50 | 0.13-0.16 | 0.18-0.24 |
| lan | 0.23-0.25 | 0.11-0.13 | 0.12-0.15 |
| Lz | 0.30-0.39 | 0.21-0.25 | 0.24-0.27 |
| lz | 0.27-0.37 | 0.25-0.27 | 0.24-0.27 |
| Lop | 0.11-0.13 | 0.08-0.13 | 0.08-0.12 |
| lop | 0.09-0.11 | 0.08-0.09 | 0.08-0.11 |
| Lbrz | 0.28-0.38 | 0.20-0.26 | 0.20-0.25 |
| lbrz | 0.35-0.40 | 0.25-0.31 | 0.22-0.25 |
| Lbrop | 0.13-0.15 | 0.11-0.14 | 0.08-0.10 |
| lbrop | 0.13-0.15 | 0.11-0.13 | 0.08-0.09 |
| Lm | —— | 0.23-0.35 | 0.25-0.33 |
| lm | —— | 0.29-0.35 | 0.25-0.26 |
| Lmop | —— | 0.07-0.09 | 0.18-0.22 |
| lmop | | 0.07-0.08 | 0.07-0.08 |
| Lav | 0.14-0.3 | 0.25-0.35 | 0.22-0.37 |
| lav | 0.15-0.26 | 0.29-0.40 | 0.19-0.25 |

Length and width of ancestrula (Lan, lan); length and width of autozooid (Lz, lz); length and width of autozooid opesia (Lop, lop); length and width of brooding zooid (Lbrz, lbrz); length and width of brooding zooid opesia (Lbrop, lbrop); length and width of male zooid (Lm, lm); length and width of male zooid opesia (Lmop, lmop); ); length and width of avicularium (Lav, lav).

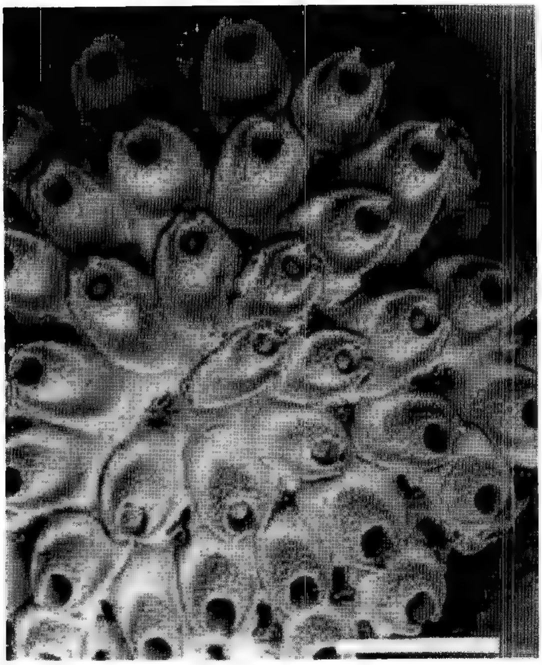

Fig. 3. *Otionella boneae* sp. nov. Whole colony with ancestrula, directed to the right and periancestrula autozooids with long gymnocysts. Scale bar = 0.50 mm.

Fig. 4. *Otionella boneae* sp. nov. Autozooids, marginal brooding zooids and avicularia. Scale bar = 0.20 mm.

raised margins but rim of cryptocyst deficient distally with small protuberances. Opesia oval. Brooding zooids with circular opesia and no protuberances. Avicularia in contiguous radial series, symmetrical with elongated open opesia and paired condyles. Mandible elongated with a terminal expansion and slightly serrated margins. Basal avicularia absent.

*Etymology*

Named for Y. Bone. Department of Geology and Geophysics, University of Adelaide.

### Remarks

*Otionellina boneae* sp. nov. resembles *O. nitida* from the southern and eastern coast of Australia in its raised zooids and contiguous radial series of avicularia. The avicularia differ in having an open opesia with no cribriform cryptocyst lamina. Another somewhat similar species, *O. zelandica* (Cook & Chimonides 1984a), has distinctly asymmetrical avicularia which only rarely occur in distal contiguous pairs marginally. The distal cryptocyst protuberances of *O. boneae* sp. nov. resemble those of fossil *O. cupola* (Tenison-Woods 1880). However, *O. cupola* has distinct brooding zooids with tubercules which *O. boneae* sp. nov. lacks (Cook & Chimonides 1985b).

*Otionellina boneae* sp. nov. appears to be a distinct Western Australian species. The two colonies from Site 85 are significantly larger (diameter 5 mm at the eighth astogenetic generation) than those from Site 101 (diameter 2.5 mm at the sixth astogenetic generation). The opercula and mandible are dark brown, the mandibles are longer than those of *O. zelandica* which they otherwise resemble. The longest, from a seventh generation position, measures 0.82 mm compared to 0.5-0.65 mm for *O. zelandica*. No basal avicularia are present at colony maturity.

Family Selenariidae Busk, 1854
Genus Selenaria Busk, 1854
Type species: *Lunulites maculata* Busk, 1852

*Description*

Colonies budded radially from an ancestrula which rarely has any adjacent avicularium. Basal surface formed by extrazooidal calcification with radial sector boundaries and pores. Autozooid opesia sometimes with paired opesiules. Colonies composed of concentric zones of closed central zooids, autozooids, female zooids and marginal male zooids. Avicularia very large, scattered, with a complex condyle and musculature system and, very often, a complete cryptocyst. Mandibles elongated and setiform.

*Selenaria* appears to be distinct from all other lunulite genera and is regarded as the only member attributable to the Family Selenariidae by Bock & Cook (1998, 1999).

**Selenaria kayae** sp. nov.
(FIGS 5, 6)

*Material examined*

*Holotype*: Sample 100B, Transect Q, 25° 17.96′ S, 112° 59.13′ E, 77.1 m, 23.i.1996, SAMA, SAM L896.

*Paratypes*: Sample 100B, Transect Q, 25° 17.96′ S, 112° 59.13′ E, 77.1 m, 23.i.1996, SAMA, SAM L897.

*Other material*: Sample 101B, Transect Q, 25° 18.29′ S, 112° 48.36′ E, 100 m, 23.i.1996, MV, F86427; Sample 102B, Transect Q, 25° 18.05′ S, 112° 33.97′ E, 121.1 m, 23.i.1996, MV, F86426; Sample 102B, Transect Q, 25° 18.05′ S, 112° 33.97′ E, 121.1 m, 23.i.1996, BMNH, 1999.11.18.2; Sample 102B, Transect Q, 25° 18.05′ S, 112° 33.97′ E, 121.1 m, 23.i.1996, UA.

*Description*

*Selenaria* with colonies reaching a diameter of 4 mm at 8 astogenetic generations and sexual maturity. Basal surface becoming flattened, with thick calcification and a distinct "edge" marginally, formed by kenozooids on the frontal surface. Sector boundaries very faint and pores absent except at the periphery. Autozooids with slightly elongated D-shaped opesia, female brooding zooids with larger opesia and very slightly raised distal rim. Male zooids with minute opesia and paired opesiules proximally. Avicularia large, with punctate cryptocyst and S-shaped condyle system. Colonies have no intact mandibles, which are assumed to have been setiform.

*Etymology*

Named for K. Conroy, the mother of the principal author.

## Remarks

*Selenaria kayae* sp. nov. closely resembles *S. minor* (Maplestone 1911) which has been redescribed by Cook & Chimonides (1985a). It differs from *S. minor* in a shorter autozooid opesia, in lacking a raised overhanging flange at the distal end of the brooding zooid and in the presence of paired opesiules in the male zooids. The flat kenozooidal "edge" of mature colonies and the large avicularia with S-shaped condyles are very like those of *S. minor*. Two other species of *Selenaria*, *S. pulchella* (MacGillivray 1895) and *S. watersi* (Cook & Chimonides 1985a), also have only the male zooids

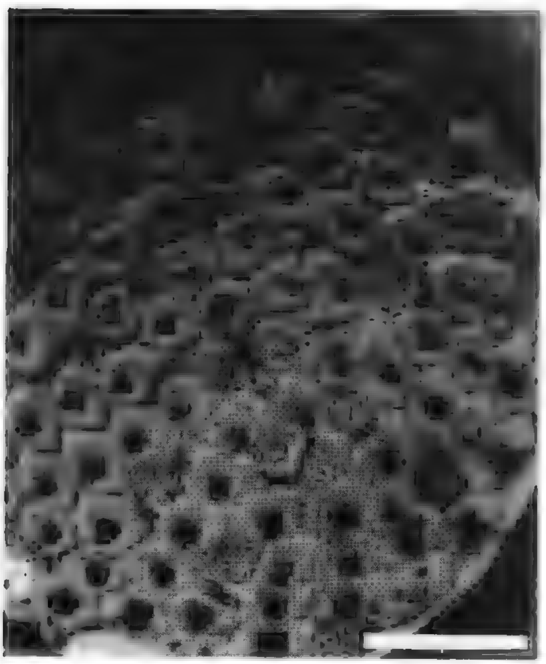

Fig. 5. *Selenaria kayae* sp. nov. Whole colony, mature, with a distinct calcified edge marginally. Scale bar = 0.50 mm.

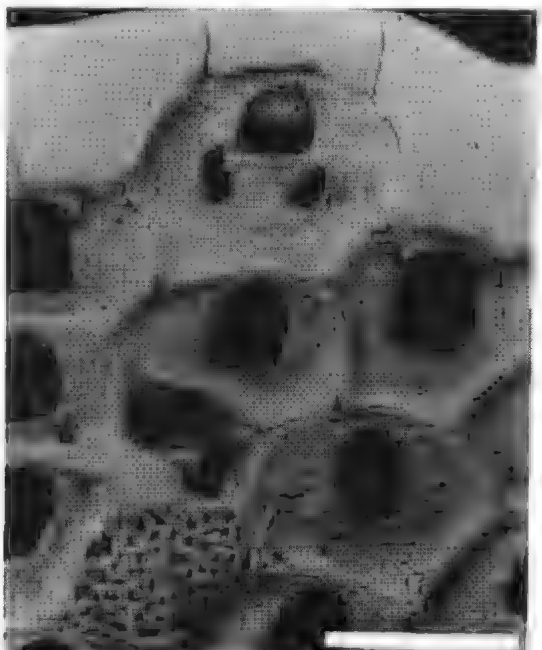

Fig. 6. *Selenaria kayae* sp. nov. Autozooids, female and male zooids, marginal kenozooids and avicularia with punctate cryptocyst. Scale bar = 0.20mm.

with opesiules but have quite different autozooidal opesiae. *Selenaria pulchella* and *S. watersi* have rounded and trifoliate opesia respectively, whilst *S. kayae* sp. nov. has elongated D-shaped opesia. *Selenaria pulchella* and *S. watersi* have avicularia with C-shaped, reflexed condyle systems in contrast to *S. kayae* sp. nov. which has S-shaped condyle systems (Cook & Chimonides 1985a).

**_Selenaria meganae_** sp. nov.
(FIGS 7-9)

*Material examined*

*Holotype*: Sample 100B, Transect Q, 25° 17.96′ S, 112° 59.13′ E, 77.1 m, 23.i.1996, SAMA, SAM L898.

*Paratypes*: Sample 100B, Transect Q, 25° 17.96′ S, 112° 59.13′ E, 77.1 m, 23.i.1996, SAMA, SAM L899.

*Other material*: Sample 101B, Transect Q, 25° 18.29′ S, 112° 48.36′ E, 100 m, 23.i.1996, MV, F86425; Sample 101B, Transect Q, 25° 18.29′ S, 112° 48.36′ E, 100 m, 23.i.1996, BMNH, 1999.11.18.3; Sample 101B, Transect Q, 25° 18.29′ S, 112° 48.36′ E, 100 m, 23.i.1996, UA.

*Description*

Colonies thinly calcified, basal surface not much thickened, with radial sector boundaries and numerous

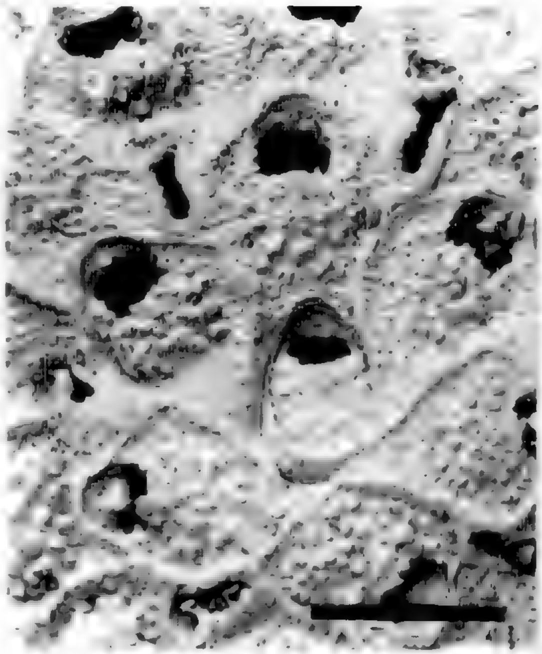

Fig. 8. *Selenaria meganae* sp. nov. Ancestrula area, directed upwards, with distinct proximal cryptocyst and no adjacent avicularia. Scale bar = 0.20 mm.

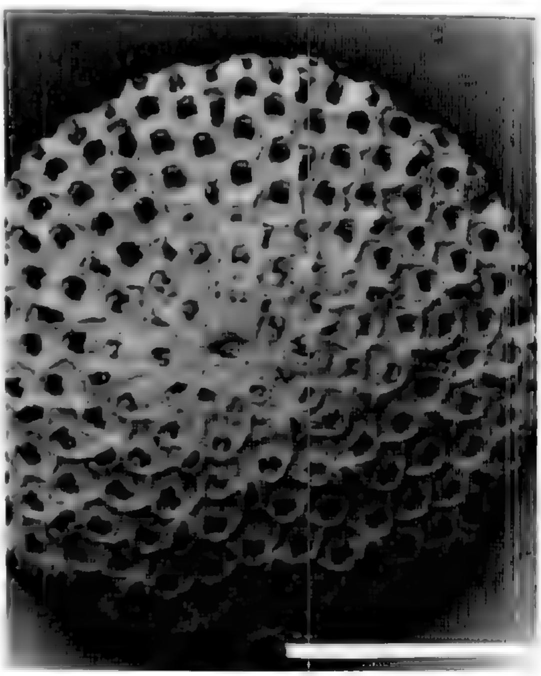

Fig. 7. *Selenaria meganae* sp. nov. Whole colony, mature, ancestrula directed left. Scale bar = 1.00 mm.

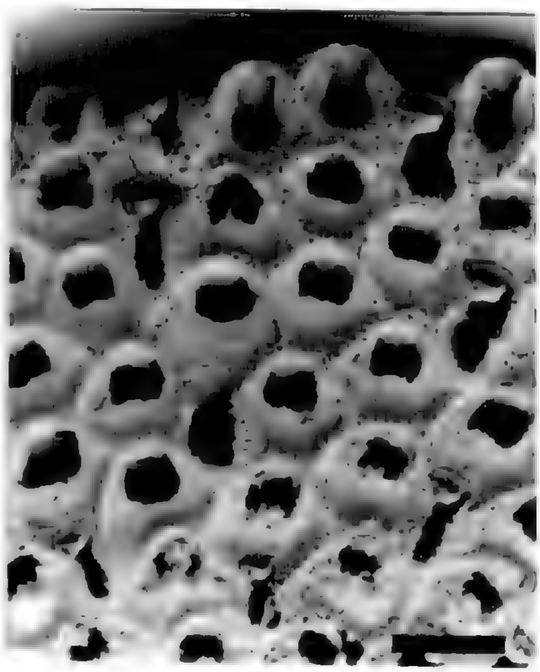

Fig. 9. *Selenaria meganae* sp. nov. Autozooids, female brooding zooids, raised distally, male zooids with narrow opesia and avicularia. Scale bar = 0.20 mm.

pores. Sexually mature at a diameter of 4 mm and the eighth astogenetic generation. Ancestrula with a distinct proximal cryptocyst and no adjacent avicularia. Autozooid opesia elongated, D-shaped, not becoming proportionally longer with astogeny. Female brooding zooids very slightly raised distally; male zooids small, with a very narrow opesia, slightly constricted laterally. Avicularia not very large, 0.22-0.37 mm in length and 0.19-0.25 mm in width, with a narrow rim of gymnocyst and cryptocyst and an elongated, open opesia. Condyle system reflexed, C-shaped; mandible not preserved, but assumed to be setiform.

*Etymology*

Named for M. Smith of Santos Ltd

## Remarks

*Selenaria meganae* sp. nov. closely resembles both *S. varians* and *S. exasperans* (Cook & Chimonides 1987). It differs from *S. varians* in the consistency of the proportions of the autozooid opesia, which do not become more elongated with astogeny. Also *S. meganae* sp. nov has narrower male zooids, (0.07-0.08 mm) compared to those of *S. varians* (0.23-0.24 mm). It differs from *S. exasperans* in the absence of any avicularia adjacent to the ancestrula and its more elongated, D-shaped autozooid opesia.

The three species of *Selenaria* appear to be closely related and form an interesting complex. It is difficult to distinguish individuals of each taxon unless the colony has a well-preserved ancestrular area and is sexually mature. *Selenaria varians* occurs with *S. meganae* sp. nov. from Western Australia. Both *S. varians* and *S. exasperans* occur together from the Great Australian Bight (Bock & Cook 1999) but most records are from Bass Strait. *Selenaria varians* is also found in New South Wales (Cook & Chimonides 1987).

## Discussion

The collections of bryozoans from Western Australia offer an estimate of the diversity and abundance of lunulite bryozoans from the South West Shelf. This also includes range extensions for several species. *Helixotionella spiralis* and *H. scutata* were previously known from the Jurien Bay district of Western Australia (Parker & Cook 1994). The samples from the South West Shelf extend the recorded range of *H. scutata* north to Cape Farquhar (approximately 23°30′ S) and of *H. spiralis* north to Zuytdorp Cliff (approximately 26°45′ S) where *Lunularia capulus* also appears. *Lunularia repanda* has now been recorded from Green Head (approximately 30° S). The range of *Otionellina australis* and *O. nitida*, together with *Selenaria maculata*, *S. punctata* and *S. varians* has also been extended even further to north of Cape Farquhar. The bathymetrical range of *H. spiralis* and *H. scutata* has been extended by 73 m to 221 m. *Selenaria maculata* and *S. punctata* are the two most common species collected from the SWS and account for more than 55% of all lunulites recovered. It is interesting to note that, although a large number of lunulite colonies was collected, the majority (79%) were not living when retrieved (Table 1).

The ecological and geographical ranges of all species, including *O. boneae* sp. nov., *S. kayae* sp. nov. and *S. meganae* sp. nov. and are tabulated in Table 2.

## Acknowledgments

We should like to thank Y. Bone (University of Adelaide) for providing most of the funds for this research project from an ARC Grant, S. Hageman (Appalachian State University, USA) for discussions on bryozoan taxonomy and life forms, M. Spencer Jones (British Museum Natural History, London) for providing registration numbers, L. Talbot and J. Farlett for scanning electron microscope training for the principal author (CEMMSA), P. Chinnock for his support during the principal author's honours year, the Oceanography Department of the CSIRO, and the Master and crew of CSIRO R.V. *Franklin* for their cooperation and assistance in the collection of samples from the South West Shelf of Western Australia.

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# A TAXONOMIC REVISION OF THE CAMPONOTUS MACROCEPHALUS SPECIES GROUP (HYMENOPTERA: FORMICIDAE) IN AUSTRALIA

*BY A. J. MCARTHUR* & S. O. SHATTUCK†*

**Summary**

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Australian ants in the Camponotus macrocephalus species group are reviewed. The group is defined here for the first time and contains eleven species including three new and one raised from subspecific to specific rank. In addition, five new synonyms are proposed. The species placed in this group are: C. anderseni sp. nov., C. annetteae sp. nov., C. conithorax Emery, C. howensis Wheeler, C. gasseri (Forel), C. janeti Forel, C. janforrestae sp. nov., C. mackayensis Forel (previously a subspecies of C. reticulatus), C. macrocephalus (Erichson), C. sanguinifrons Viehmeyer and C. vitreus (Smith). The new synonyms are: C. gasseri coloratus Wheeler, C. gasseri lysias Forel and C. gasseri obtrusitrumcatus Forel with C. gasseri and C. fictor augustulus Viehmeyer and C. semicarinatus Forel with C. macrocephalus. The queens and major workers of these species display varying degrees of phragmosis from weak to very strong and the worker caste is dimorphic. Most are arboreal nesters.

Key Words: Hymenoptera, Formicidae, Formicinae, Camponotus, arboreal ants, phragmosis.

*Transactions of the Royal Society of S. Aust.* (2001), **125**(1), 25-43.

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by A. J. McArthur* & S. O. Shattuck†

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Key Words: Hymenoptera, Formicidae, Formicinae, *Camponotus*, arboreal ants, phragmosis.

## Introduction

Species in the genus *Camponotus* Mayr are widespread in Australia yet few of the 120 described species can be identified with certainly because revision of the group is lacking. Characters defining *Camponotus* in Australia are described by Shattuck (1999). Our objective here is to define a small group of apparently related species and revise them at species level. Identification of the mainland species is based on characters of minor workers as majors seldom leave the nest and are therefore infrequently encountered. This will be especially useful for those using ants as environmental indicators particularly when monitoring disturbance (Hoffman *et al.* 2000).

### *The subgenus* Colobopsis

Most of the species treated here have been placed in the subgenus *Colobopsis* Mayr by earlier workers. The exceptions are *Camponotus janeti* Forel and *C. mackayensis* Forel which were placed in subgenus *Myrmamblys* Forel.

Mayr (1861) established both *Camponotus* and *Colobopsis* as full genera. Emery (1889) first proposed *Colobopsis* as a subgenus of *Camponotus* although Bingham (1903) continued to recognise *Colobopsis* as a genus. Wheeler (1904) supported Emery's subgeneric concept and subsequent workers have followed suit. The subgeneric classification of *Camponotus* has not proven particularly useful. Emery (1896) was the first to attempt to subdivide the genus into subsets by creating 26 subgenera. However, Forel (1914) disagreed with the proposed classification as he found it impossible to "disentangle the natural phylogeny of the genera". Later, Emery (1925) listed 40 subgenera created by himself and others and produced a key based on morphological characters. He characterized *Colobopsis* as "head more or less cylindrical and obliquely truncated" and *Myrmamblys* as "head more or less distinctly truncated or obtuse anteriorly". He placed *conithorax* Emery, *fictor* Forel, *gasseri* Forel, *sanguinifrons* Viehmeyer and *vitreus* Smith in the subgenus *Colobopsis* and *janeti* Forel and *mackayensis* Forel in the subgenus *Myrmamblys*. These placements have been followed, without comment, since.

The subgeneric classification was queried by Brown (1972). He described it as "weak and inconsistent". This view was repeated by Bolton (1995) who stressed that many of the subgenera in *Camponotus* "were weak, poorly defined and untrustworthy". We support this view and can find little utility in the current classification. This is especially true for the subgenus *Colobopsis*. The subgenus has accumulated species of *Camponotus* which are phragmotic with little critical analysis of how they may be related to other phragmotic species. It is apparent that a number of unrelated groups has been artificially assembled within this subgenus and the group is undoubtedly polyphyletic. This is based on the morphology of the mesosoma, especially that of the propodeum, the mandibular dentition and the clypeal structure and its relationship with phragmotism in major workers (in some species the

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posterior region of the clypeus is angled; in others it is flat). Unfortunately, resolving the *Colobopsis* predicament will require examining a wide range of taxa on a world-wide basis, an undertaking well outside the scope of the current project. Because of this, the species group proposed here may be broken into a number of groups in the future. However, the purpose of this paper is to resolve the species-level taxonomy of part of the Australian *Camponotus* fauna. We believe the recognition of this group is acceptable as it forms a moderate sized group that is well defined, a situation not found previously.

The *Camponotus macrocephalus* species group as described here should not be confused with the *C. ephippium* species group, the description of which is in preparation. *Camponotus ephippium* group major workers have been observed using their heads to block soil nest entrances but the truncated portion of the anterior head is rounded and not as flat, the fore femurs are not swollen, and the cheeks are swollen compared with *C. macrocephalus* group species. Also, *C. ephippium* group species nest in soil whereas *C. macrocephalus* group species generally nest in trees.

## Material

*Measurements*

CAR W = maximum frontal carina width; CLY W = clypeus width measured between tentorial pits; EL = eye length in dorsal view; HW = maximum head width in dorsal view; HT = maximum head thickness in lateral view; HL = head length measured from anterior margin of clypeus to vertex; PW = maximum pronotal width in dorsal view; NW = node width in dorsal view; TL = length of mid tibiae.
Scale lines = 1 mm.

*Location of material examined*

ANIC = Australian National Insect Collection, Canberra, ACT; Curtin = Curtin University, WA; GMNH = Museum d'Histoire Naturelle, Geneva, Switzerland; MCG = Museo Civico di Storia Naturale "Giacomo Doria", Genoa, Italy; MCZ = Museum of Comparative Zoology, Harvard University, Cambridge, USA; SAMA = South Australian Museum, Adelaide, SA; ZMB = Museum fur Naturkunde an der Universitaet Humboldt zu Berlin, Germany.

*Collectors of material examined*

AC, A. Calder; AJM, A. J. McArthur; ALH, A. L. Hertog; AML, A. M. Lea; AS, A. Salvarani; AZG, Adelaide Zoo Guides; BBL, B. B. Lowery; BFR, B. F. Rogers; BJW, B. J. Walker; BPM, B. P. M. Hyland; CDM, C. D. Michener; DHC, D. H. Colless; DJC, D. J. Cook; DPIQ, Department of Primary Industry, Queensland; EC, E. Cameron; EFR, E. F. Rick; EGM, E. G. Mathews; EK, E. Kearney; EY, E. Yeatman; FAC, F. A. Cudmore; FPD, F. P. Dodd; Feu, Feuerherdt; GCh, G. Churchett; GBM, G. B. Monteith; GFG, G. F. Gross; GFH, G. F. Hill; GT, G. Turner; IDN, I. D. Naumann; J&NL, J. & N. Lawrence; JAF, J. A. Forrest; JAH, J. A. Herridge; JAh, J. Ahlers; JBS, J. B. Stuckey; JCC, J. C. Cardale; JCG, J. C. Goudie; JCl, J. Clark; JDM, J. D. Majer; JEF, J. E. Feehan; JJD, J. J. Davis; JMc, J. McAreavey; JS, J. Sedlacek; JT, J. Toma; KP, K. Pullen; LHM, L. H. Minchin; LW, L. Weatherill; MJN, M. J. Neave; MLS, M. L. Simpson; NMH, N. M. Hudson; PJF, P. J. Fargher; PJM, P. J. M. Greenslade; PSW, P. S. Ward; RAB, R. A. Barrett; RAP, R. A. Perkins; RE, R. Eastwood; RHM, R. H. Mew; RR, R. Robinson; RSB, R. S. Bungey; RVS, R. V. Southcott; RWT, R. W. Taylor; SOS, S. O. Shattuck; SEF, South Australian National Parks South East Fauna Survey; TAW, T. A. Weir; TC, T. Croft; TG, T. Greaves; Tur, Turner; WCC, W. C. Crawley; WLB, W. L. Brown; WMW, W. M. Wheeler; WR, W. Rafferty; YS, Y. Sakuri.

### Genus *Camponotus* Mayr 1861

*Diagnosis of* Camponotus macrocephalus *species group workers in Australia*

Fore femurs swollen, much greater in diameter than middle and hind femurs, generally more swollen than in most other *Camponotus* species (Fig. 1). Major workers and queens show distinct phragmosis, i.e. the anterior of the head is truncated

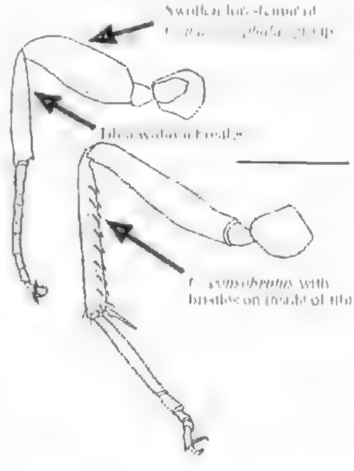


Fig. 1. *Camponotus macrocephalus* group. Morphology of the fore leg showing the swollen fore femur and absence of tibial bristles compared with *C. consobrinus*. Scale bar = 1 mm.

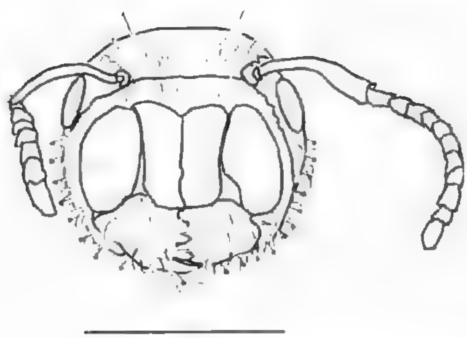


Fig. 2. *Camponotus sanguinifrons*. Anterior view of head of major worker showing phragmosis and clavate setae. Scale bar = 1 mm

and flattened (Fig. 2). Workers are dimorphic, i.e. major and minor workers have practically no intermediaries as shown by head measurements (Fig. 11). Spines or bristles on the lower surfaces of the tibiae lacking, or at most, only one or two (most *Camponotus* species possess two rows of 5 to 10 spines) (Fig. 1).

The *Camponotus macrocephalus* species group can be divided into three complexes as follows:
1. *vitreus* complex: comprises *annetteae*, *conithorax*, *gasseri*, *janforrestae* and *vitreus*. This group is characterised by the depressed metanotal groove and high, arched propodeum.
2. *macrocephalus* complex: comprises *anderseni*, *howensis* and *macrocephalus*, all possessing a flat mesosomal dorsal surface and an elevated propodeal angle
3. *janeti* complex: comprises *janeti*, *mackayensis* and *sanguinifrons*, all possessing a more evenly convex mesosoma.

*Biology*

Nests of these ants are generally found in galleries or tunnels which had been constructed in trees and shrubs by another insect. The nests are common in dead and living branches where the diameter exceeds 40 mm. Nests usually have only one entrance which is blocked in a remarkable way. A major worker uses its head like a cork to close the circular entrance, the diameter of which is only slightly greater than the worker's head. The heads of major workers and queens are more or less circular in cross section with the anterior portion truncated, flat and often deeply and coarsely sculptured, camouflaging the entrance when it is blocked. When the 'door keeper' removes its head from the hole, there is enough space to allow a nest mate to pass. Major workers are able to act as living doors because they have evolved a characteristic flat or phragmotic face (from Greek *phragmos*, 'fence' or 'fencing in'). Wheeler (1904) has shown that workers wishing to gain entry appear to communicate to the 'door keeper' by its clypeus or mandibles, as all other sensitive parts, notably the eyes and antennae, are too far out of reach to receive stimuli from outside the entrance. Wheeler (1904) and Donisthorpe (1948) suggest that in Europe, workers of *Camponotus* (*Colobopsis*) *truncata* Spinola (1808) are capable of excavating hard wood for their homes, a habit not found in Australian species which show a preference for rotten wood or preformed cavities. In Australia, galleries used by these ants are probably excavated primarily by termites.

### Key to the minor workers *Camponotus macrocephalus* species group in Australia

1. Number of erect setae on dorsum of mesosoma greater than 5 . . . . . . . . . . . . . . . . . . . . . . . . 2
   Number of erect setae on dorsum of mesosoma less than 5 (often 0) . . . . . . . . . . . . . . . . . . . 6
2. Erect setae on dorsum of mesosoma short (length < half EL) (Figs 5, 6) . . . . . . *annetteae* sp. nov.
   Erect setae on dorsum of mesosoma long (length > half EL) . . . . . . . . . . . . . . . . . . . . . . . . . 3
3. Dorsal surface of propodeum concave (Figs 18, 19) . . . . . . . . . . . . . . . . . . *mackayensis*
   Dorsal surface of propodeum flat or convex . . 4
4. Dorsal surface of propodeum flat or weakly convex (Figs 14, 15) . . . . . . . . . . . . . . *janeti*
   Dorsal surface of propodeum strongly convex and dome-like. . . . . . . . . . . . . . . . . . . . . . 5
5. Underside of head with erect setae (Figs 16, 17) . . . . . . . . . . . . . . . . . . *janforrestae* sp. nov.
   Underside of head lacking erect setae (Figs 24, 25) . . . . . . . . . . . . . . . . . . . . . . . . . . *vitreus*
6. Propodeum separated from mesonotum by an angular metanotal groove . . . . . . . . . . . . . . . . 7
   Propodeum and mesonotum in approximately the same plane and forming a continuous surface; metanotal groove essentially absent . . 8
7. Propodeum cone-like, its dorsal and posterior faces meeting in an angle (Figs 7, 8) . . . . . . . . . . . . . . . . . . . . . . . . . . . *conithorax*
   Propodeum hemispherical, its dorsal and posterior faces rounding gradually into each other (Figs 9, 10) . . . . . . . . . . . . . . . . . . *gasseri*
8. Dorsal face of propodeum relatively long compared to posterior face (ratio propodeal dorsum/declivity > 1,5) (Figs 22, 23) . . . . . . . . . . . . . . . . . . . . . . . . . . *sanguinifrons*
   Dorsal face of propodeum relatively short compared to posterior face (ratio propodeal dorsum/declivity < 1,5). . . . . . . . . . . . . . . . . 9
9. Eyes placed anteriorly, much closer to mandibles than vertex (Figs 3, 4) . . . . *anderseni* sp. nov.
   Eyes placed near midline of head, slightly closer

to vertex than mandibles. . . . . . . . . . . . . . . . 10

10\. Mandibles in major workers smooth and with shallow fovae, rugae weak and limited to the anterior region of the dorsal surface; limited to mainland Australia (Figs 20, 21) . . . . . . . . . . . . . . . . *macrocephalus*

Mandibles in major workers with distinct rugae superimposed over shallow fovae, the rugae covering the entire dorsal surface; occurring on Lord Howe Island (Figs 12, 13) . . . . . *howensis*

### *Camponotus anderseni* sp. nov.
(FIGS 3, 4)

*Holotype*: One major worker, pinned, Northern Territory, Leaders Ck, Gunn Point, 9/5/98, ALH (SAMA).

*Paratypes*: Three major workers and three minor workers in alcohol, same data as holotype (SAMA, ANIC).

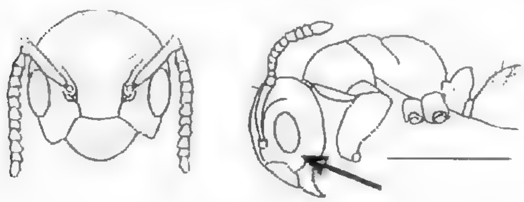
*Worker diagnosis*

Mesosoma glossy with only a few erect setae and very sparse indistinct flat-lying setae, tibiae with slightly raised setae; eyes large, elongated, placed closer to mandibles than vertex (Fig. 3).

*Worker description*

Major worker. In lateral view. Head: Yellowish brown, grading darker posteriorly, side with plentiful small punctations spaced just greater than their diameter. Plentiful, short, erect setae tending sparse on the side, with sparse flat-lying setae; antennae same color as anterior head, vertex with a few short, thick setae, underside of head without erect setae, eye large, much longer than wide, closer to mandibles than vertex. Pronotum: Light red brown, similar to anterior head, flatly convex with distinct prosternal structure, dorsum without setae or pubescence. Mesonotum: Light red brown slightly darker than head, mostly straight, dorsum without setae. Metanotum: Distinct, narrow, spiracle scarcely protruding. Propodeum: Light red brown, slightly darker than rest of mesosoma, dorsum and declivity mostly straight separated by widely rounded right angle, glossy, without pubescence; declivity short, straight, upright; spiracle situated four or five diameters anterior to declivity. Node and gaster: Brown, darker than mesosoma. Node: Without pubescence, anterior face convex, summit rounded, posterior face mostly straight. Gaster: Glossy. Fore femur: Brown grossly swollen. Mid tibia: Without pubescence, with few adpressed short setae outside, without bristles inside. In dorsal view. Head: Sides, parallel mostly straight; vertex and angles forming even convexity; scape without pilosity, thickened towards funiculus. Frontal carinae straight, diverging to wider than half HW; frontal area diamond shaped, anterior margin distinct, max HW at eye centre. Clypeus, frontal lobes and most of frontal area sunken. Clypeus: Anterior margin projecting, convex, integument finely shallowly punctate with plentiful very short, erect setae, without pubescence, without carina. In front or rear view. Node summit: Straight, wide, with few long setae. In top view. Node: Posterior surface flat, anterior convex.

Minor worker. In lateral view. Mesosoma, node, gaster and posterior head similar reddish brown, anterior head lighter. Head: Side with few small indistinct punctations, sparse, short, flat-lying setae; underside of head without long setae; scape and funiculus same color as anterior head; vertex with one or two short thick setae; eye nearly twice as long as wide, closer to mandibles than vertex. Pronotum: Anterior and posterior halves flat, separated by widely rounded angle, without setae. Mesonotum: Flatly convex, dorsum with one or two very short erect setae. Metanotum: Transverse, narrow; spiracle prominent, well below dorsum. Propodeum: Glossy, dorsum and declivity form even convexity, dorsum with few very short adpressed setae, ratio dorsum/declivity approximately 1; spiracle surrounded by glossy integument, without pubescence, situated four or five diameters anterior to declivity. Node: Without pubescence, anterior face mostly straight; summit rounded; posterior face mostly straight. Gaster: Glossy. Fore coxa: Light red brown, slightly darker above. Fore femur: Red brown, same color as mesosoma, grossly swollen.



Figs 3, 4. *Camponotus anderseni* sp. nov. 3. Minor worker, head and mesosoma. The eye is large and close to the mandibles. Fig. 4. Known distribution. Scale bar = 1 mm.

Fore tibia and Fore tarsus: Red brown same as mesosoma. Mid tibia: With few decumbent and adpressed short setae, without bristles inside. In dorsal view. Head: Sides and vertex evenly rounded; scape without pilosity, thickened towards funiculus; frontal carinae straight, diverging to wider than half HW; frontal area diamond shaped with distinct anterior margin; max. HW at eye centre. Clypeus: Finely and sparsely punctate, without pubescence, few setae around margin, without carina; anterior margin projecting, convex, wide. In front or rear view. Node summit: Widely rounded with a few setae.

*Measurements*

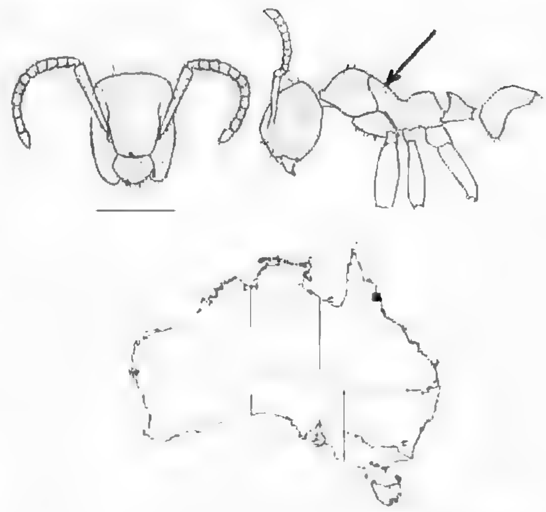
HW 0.80-1.20 mm, HL 0.90-1.30 mm, PW 0.60-0.90 mm, HT 0.60-0.95 mm, EL 0.32-0.35 mm, CARW 0.45-0.95 mm, CLYW 0.45 mm, TL 0.65-0.75 mm.

*Etymology*

Named after A. N. Andersen who recognised the uniqueness of this ant.

### Remarks

This species has been found nesting in the mangrove *Sonneratia alba* J. Smith in the Northern Territory and Kimberley region of Western Australia (Fig. 4). At high tide the nests are submerged and during these times major workers use their heads to block nest entrances (A. N. Andersen, pers. comm. 2000). While this species is rare and known from only a small number of specimens, it is distinct from all others in this group.



Figs 5, 6. *Camponotus annetteae* sp. nov. 5. Minor worker head and mesosoma. Pilosity is plentiful. 6. Known distribution. Scale bar = 1 mm.

### *Camponotus annetteae* sp. nov.
(FIGS 5, 6)

*Holotype:* One minor worker pinned. Cairns, Queensland, 9/8/75, BBL (ANIC).

*Paratype:* One minor worker, same data as holotype (ANIC).

*Worker diagnosis*

Whole ant clothed in short erect setae. Mesosoma with a deep, wide depression ahead of the propodeum which is raised into a dome (Fig. 5).

*Worker description*

Minor worker. Whole ant covered with plentiful white, short, upstanding setae; red except for slightly lighter limbs and dark brown posterior gaster. In lateral view. Head: Glossy, indistinctly reticulate, few punctations, vertex bluntly margined. Pronotum: High dome with anterior and posterior halves straight, dorsum with few flat-lying additional setae, feebly punctate. Mesonotum: Straight, long. Metanotum: Wide deep trough 0.25 mm wide with spiracles protruding to level of dorsal surface. Propodeum: Domed, near hemispherical, angle well rounded, declivity straight; spiracle protruding rearward surrounded by smooth, glossy, integument with a few short erect and flat-lying setae. Node: High, anterior face strongly concave; summit sharp, leaning forward; posterior face convex. Gaster: Red anterior, black posterior, glossy, smooth, fine flat-lying pubescence. Fore femur: Swollen. Mid tibia: Plentiful sub-erect setae outside, without bristles inside. In dorsal view. Head: Sides, posterior halves slightly convex, tapering in slightly; anterior halves straight, parallel; cheeks slightly swollen, vertex, nearly straight, scape with plentiful short erect setae. Frontal carinae very wide diverging strongly scarcely converging posteriorly. Anterior extremities of frontal carinae continuing transversely, forming a step along posterior clypeus; frontal area narrow transverse; max HW well anterior to eye centre, eyes situated less than half eye width from corners. Clypeus: Wide, slightly striate with elongated punctations, no truncation, glossy with plentiful short setae, carina distinct as narrow ridge on flattish clypeus, anterior margin lateral fifths intruding, median three fifths projecting evenly convex. In front or rear view. Node: Summit widely and deeply indented with plentiful short erect setae.

*Measurements*

HW 1.4 mm, HL 1.5 mm, PW 1.05 mm, HT 0.95 mm, EL 0.3 mm, CAR W 0.85 mm, TL 1.3 mm.

*Etymology*
Named after A. Vincent, a scientific illustrator.

**Remarks**

This rare species is apparently restricted to Far North Queensland (Fig. 6). B. B. Lowery collected specimens from street trees in Cairns and noted that it appeared to mimic a red species of *Podomyrma*. Although *C. annetteae* is known from only two specimens it is highly distinctive and unlikely to be confused with any other species.

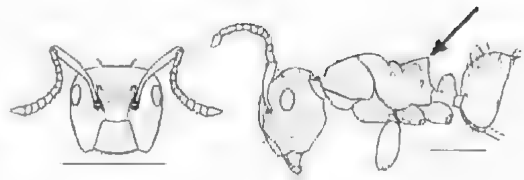
*Camponotus conithorax* Emery
(FIGS 7, 8)

*Camponotus (Colobopsis) conithorax* Emery 1914: 430.
*Type examined*: One male labelled "Camp conithorax Emery" "Port Sandwich" "Mus Civ Gen." "Museum Paris Nouv Hebrides III. Mallicolo Dr Joly 1903" (MCG).

*Other material examined*: Queensland: Lockerbie, 10°48′ S 142°28′ E, 15/6/69, GBM (ANIC); Bamaga, 10°53′ S 142°24′ E, Feb-80, BPM (ANIC).

*Worker diagnosis*
Propodeum appears conical when viewed from side, upper and posterior surfaces straight and separated by an angle just greater than 90°. Scapes and tibiae with plentiful short fine setae, raised to an angle of about 10°. Very few erect setae on the outer surface of the head and none on the under side (Fig. 7).

*Worker description*
Major worker. In lateral view. Pronotum, anterior mesonotum, limbs and gaster brown, posterior mesonotum, propodeum and node darker brown, nearly black. Head: Dark brown, lighter in front; side glossy, smoothly reticulate with very sparse flat-lying short setae; scape dark brown like posterior head; funiculus lighter like anterior head; vertex with one or two erect setae; underside of head without erect setae, with few very short adpressed setae. Pronotum: Glossy, flatly convex, dorsum with one or two long setae, without pubescence. Mesonotum: Glossy, evenly convex without setae or pubescence. Metanotum: Separated from mesonotum and propodeum by deep transverse cuts raised up in centre; spiracles placed well below dorsum, slightly protruding upward. Propodeum: Posterior dorsum inclined upward, conical, glossy, with few short adpressed setae; angle approximately 90°, sharply rounded; declivity mostly straight; ratio dorsum/declivity approximately 1; spiracle



Figs 7–8. *Camponotus conithorax*. 7. Minor worker, head and mesosoma. Propodeal angle is conical. 8. Known distribution of *C. conithorax*. Scale bars = 1 mm

protruding to rear, surrounded by glossy integument with a few short indistinct flat-lying setae. Node: Glossy with sparse flat-lying and sparse erect, short setae; anterior face convex above; summit blunt; posterior face straight. Gaster: Dark brown, lighter posteriorly; glossy. Fore femur: Swollen. Mid tibia: Plentiful short, decumbent setae, without bristles inside. In dorsal view. Head: Sides straight, parallel; vertex straight; scape with sparse, short flat-lying setae; frontal carinae wide, diverging strongly then converging slightly at posterior; frontal area diamond shaped with an anterior pit; max HW at eye centre. Truncation: Near posterior clypeus. Clypeus: Sides mostly parallel, long, diverging anteriorly, with few feeble striations and punctations, without furrows, glossy, with few very sparse, flat-lying setae, anterior margin projecting, mostly straight with weak median concavity, with few long setae; without carina. In front or rear view. Node: Narrow, summit straight with few short setae.

Minor worker. In lateral view. Pronotum, anterior mesonotum and gaster brown; posterior mesonotum, propodeum and node darker brown, limbs a little lighter coloured than mesosoma. Head: Dark brown, grading to yellowish brown anteriorly, side with sparse flat-lying short setae; glossy, smoothly reticulate; scape dark brown, like posterior head; funiculus lighter, like anterior head, vertex with sparse, short, flat-lying setae; underside of head without erect setae, with few very short, adpressed setae. Pronotum: Anterior third convex, otherwise straight without setae or pubescence. Mesonotum: Evenly flatly convex, dorsum without setae or pubescence. Metanotum: Separated from mesonotum and propodeum by deep transverse cuts, raised in the centre; spiracles placed well below dorsum, slightly protruding up. Propodeum: Dark brown with few short adpressed setae; dorsum slightly convex, slightly inclined upward; angle blunt 90°; declivity very straight; ratio dorsum/declivity near 1; spiracle protruding to rear surrounded by glossy integument with few short, sparse setae. Node: Glossy with few very short, erect setae; petiole with ventral protuberance; lower half of anterior face of node straight, otherwise convex; summit blunt; posterior face mostly straight. Gaster: Glossy. Fore femur: Swollen. Mid tibia: With short decumbent setae, lacking bristles inside. In dorsal view. Head: Sides flatly convex, tapering to front; vertex convex, scape with sparse, short, flat-lying setae; frontal carinae wide, nearly parallel; frontal area diamond shaped, indistinct; max HW at eye centre. Clypeus: Glossy with few sparse flat-lying and erect setae, without carina; anterior margin wide, mostly straight, projecting but not beyond cheeks. In front or rear view. Node: Narrow, summit rounded with few erect long setae.

*Measurements*
HW 1.5-2.1 mm, HL 1.6-2.3 mm, PW 1.1-1.3 mm, HT 1.2-1.6 mm, EL 0.4-0.5 mm, TL 1.6-1.9 mm.

## Remarks

Emery (1914) described minor workers from Vanuatu (then the New Hebrides). The major worker is described here for the first time. The identity of the Australian specimens is based on comparison with the only known type specimen (a male paratype) and the brief description (Emery 1914, including Fig. 18 in Plate 13). BMP collected specimens nesting in a hollow twig of *Endospermum* at Bamaga, Qld.

### *Camponotus gasseri* (Forel)
(FIGS 9-11)

*Colobopsis gasseri* Forel 1894: 233.
*Camponotus (Colobopsis) gasseri* Forel 1902: 507 Combination.
*Camponotus (Colobopsis) gasseri* Forel 1912: 90
*Camponotus (Colobopsis) gasseri lysias* Forel 1913: 193.
*Camponotus (Colobopsis) gasseri obtrusitruncatus* Forel 1902, 508.
*Camponotus (Colobopsis) gasseri obtrusitruncatus* Emery 1925: 148 Spelling change.
*Camponotus (Colobopsis) gasseri coloratus* Wheeler 1934: 162.

*Types examined*: *Camponotus gasseri*. Typus, from Perth, W. A., major and minor workers, Box 176 (GMNH). *Camponotus gasseri obtrusitruncatus*. Typus, from Mackay, Qld. major and minor workers, Box 176 (GMNH). *Camponotus gasseri lysias*. Typus, from Ulverstone, Tas., three workers, Box 176 (GMNH).

*Other material examined*: Australian Capital Territory; Black Mountain, 1931, TG (ANIC); Canberra, 1935, TG (ANIC); Kowen, Brindabella Range, 1932, TG (ANIC); Red Hill, 1931, TG (ANIC); Uriarra, 1931, TG (ANIC). New South Wales; Armidale, 1982, YS (ANIC); Berrigan State Forest, 1979, BBL (ANIC); Braidwood Road, 1935, TG (ANIC); Brookvale, 1931, TG (ANIC); Burns Bay, Lane Cove, 1959, BBL (ANIC); Guyra, 2 mi. S 1949, TG (ANIC); Kioloa State Forest, 1998, SOS (ANIC), Mt Wog Wog, 4 km NE, 1986, TAW (ANIC); Nyngan, 1948, JMc (ANIC); Port Macquarie, 1968, KP (ANIC); Ryde Caravan Pk., 1966, RHM (SAMA); Wyong National Forest Ourimba, 1967, BBL (ANIC). Queensland; Beerwah, 1958, CDM (ANIC); Beerwah, JDM (Curtin), Beerwah State Forest, 1958, CDM (ANIC); Cairns, 1971, BBL (SAMA); Upper Gayundah Creek, 1984, GBM, DJC (ANIC). South Australia: Adelaide Botanic Park, 2000, AZG (SAMA); Aldinga, 1987, JAF, EGM (SAMA); Aldinga, 2000, AJM, PJF (SAMA); Aldinga, 3 km SW, 1989, PSW (ANIC); American R., 1973, PJM (SAMA); Banff, 1975, PJM (ANIC); Belair, 1999, AJM (SAMA); Belair, 1973, PJM (ANIC); Beltana, 15 km ENE, 1975, PJM (SAMA); Breakneck R., 1973, PJM (ANIC), Burnside, Undelcarra, 1996, MLS (SAMA); Cape

Figs 9, 10. *Camponotus gasseri*. 9. Minor worker, head and mesosoma. Propodeum is humped and glabrous. 10. Known distribution. Scale bars = 1 mm.

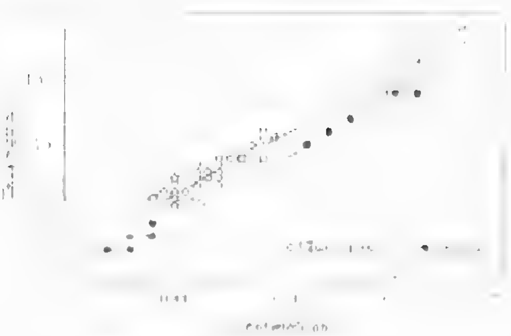


Fig. 11. Graph showing dimorphism in head dimensions of *Camponotus gasseri* from Glen Osmond, South Australia (n = 60, $R^2$ = 0.95) and from Beerwah, Queensland (n = 10, $R^2$ = 0.99). Queensland specimens were smaller.

Bonda, 8 mi E, 1973, PJM (SAMA); Ceduna, 10 mi SE, 1975, JAH (SAMA); Clare, 1950, JMc (ANIC); Dudley CP, GCh (SAMA); Ferries Macdonald CP, 1964, GFG (SAMA); Flinders I., 1987, JEF, MJN (ANIC); Glen Osmond, 1976, PJM (ANIC); Greenly I. (SAMA); Kangaroo I., AML (SAMA); Hanson Bay, 1973, PJM (ANIC); Head of Great Australian Bight, 1988, JAF (SAMA); Innes CP, 1976, PJM (SAMA); Kalangadoo, 15 km W, 1995, BFR (SAMA); Kelly Hill Caves, 1972, PJM (ANIC); Kongorong, 1997, SEF (SAMA); Little Dip CP, 1978, PJM (SAMA); Loftia Pk, 1990, JAF (SAMA); Lucindale, Feu (SAMA); Meningie, LHM (SAMA); Meningie, 10 km SW, 1974, PJM (SAMA); Minghool, 1987, AJM (SAMA); Mt Benson, 21 km NE, 1997, SEF (SAMA); Mt Compass, 1969, BBL (SAMA); Mt Compass, 1969, BBL (ANIC); Mt Lofty, 1978, EY (ANIC); Mt Remarkable CP, 1973, PJM (ANIC); Mt Rough, 5 km W, 1972, PJM (ANIC); Naracoorte Cave CP, 1958, GFG (SAMA); Nappyalla, 1 km W, 1984, RR (SAMA); Norwood, 1971, BBL (SAMA); Oraparinna, 1971, PJM (ANIC); Portee, 1999, AJM (SAMA); Ravine Des Casoars, 7 km N, 1990, EGM, JAF (SAMA); Reevesby I., 1936, JCI (SAMA); Riverton, 1975, PJM (ANIC); Rocky R., 1972, PJM (ANIC); Sandy Ck, 1972, PJM (ANIC); Sevenhill, 1957, BBL (ANIC); Spalding Cove, 1973, PJM (ANIC); Streaky Bay, 1957, BBL (ANIC); Tintinara, 10 mi. E, 1958, TG (ANIC); Umberatana, 1975, PJM (ANIC); Umberatana, 15 km NE, 1975, PJM (ANIC); Western Flat, 8 km S, 1994, TC (ANIC). Tasmania: Asbestos Ra., 1991, BBL (ANIC); Asbestos Ra., 1990, BBL (SAMA); Bakers Beach, 1992, BBL (SAMA); Bakers Beach, 1993, BBL (SAMA); Bruny I. Aerodrome, 1992, BBL (SAMA); Burnie, 5 km E, 1994, BBL (SAMA); Devonport, The Bluff, 1993, BBL (SAMA); Flinders I., 1992, BBL (SAMA); Furneaux Lookout, 1992, BBL (SAMA); Great Bay, North Bruny I., 1992, BBL (SAMA); Hobart, AML (SAMA); Hobart, 1938, FAC (ANIC); Hobart, 1951, NMH (ANIC); Hobart, 1935, WR (ANIC); Launceston, 1915 (SAMA); Lavinia Res, King I., 1992, BBL (ANIC); Maria I., 1992, BBL (SAMA); Mt Tanner, 1991, BBL (SAMA); Mt Wellington 500m slope, 1991, BBL (SAMA); North Bruny I., 1992, BBL (SAMA); Port Sorell, 1992, BBL (SAMA); Rocky Cape Sisters Beach, 1994, BBL (SAMA); Seal Rocks, King I., 1991, BBL (SAMA); Surprise Bay, 4 km N, 1994, BBL (SAMA); Swansea, 1962, LW (SAMA); Swansea, Nine Mile Beach, 1996, BBL (ANIC); Hobart, AML (SAMA); Tunbridge, 1992, BBL (SAMA); Walkers Lookout, 2 km N, 1995, BBL (SAMA). Victoria: Aireys Inlet, 1945, JMc (ANIC); Greensborough, JMc (ANIC); Hurstbridge, 1958, BBL (ANIC); Orbost, 1959, GFG (SAMA); Springvale, RVS (SAMA); Ultima, JCG (SAMA). Western Australia: Cunderdin, 1 km E, 1985, PSW (ANIC); Darlington, 1969, BBL (ANIC); Dryandra, 1982, JDM (Curtin); Esperance, 1970, BBL (SAMA); Esperance, 1970, BBL (ANIC); Junana Rock, 1977, RWT (ANIC); Kings Park, 1969, BBL (ANIC); Mt Ragged, 11 km NW by N, 1969, RWT (ANIC); Mundaring Weir, JCI (ANIC); Nornalup, 1984, J&NL (ANIC); Norseman, 15 km ENE, 1969, RWT (ANIC); Norseman, 4 km NNE, 1969, RWT (ANIC); Northampton, 5 km N, 1985, PSW (ANIC); Pingrup, 1958, TG (ANIC); Stirling Ra. NP, 1984, J&NL (ANIC); Widgiemooltha, 8 mi. N by W, 1969, RWT (ANIC); Worsley, JDM (Curtin); Yanchep, JDM (Curtin); Zanthus, 1 mile SE by E, 1969, RWT (ANIC).

*Worker diagnosis*

A few erect setae on the front of the head and gaster; none elsewhere. Mesosoma glossy with propodeum raised to hemispherical dome (Fig. 9).

*Worker description*

Major worker. Whole ant varies from black with patches of red or red brown to occasionally all red. In lateral view. Head: Side without erect setae, posterior three quarters, very finely punctate; anterior quarter striate, truncation 135° abrupt; vertex with a few setae; underside of head without setae. Pronotum and mesonotum forming rounded symmetrical hump, slightly flattened on top, without setae. Metanotum: Two distinct transverse sutures at bottom of a trough, spiracle directed upward, placed below dorsum. Propodeum: Without setae, dorsum hemispherical dome; angle rounded; declivity straight; ratio dorsum/declivity approximately 1; spiracle placed midway between dorsum and coxa, surrounded by fine reticulations and very sparse, short, flat-lying, coarse setae. Node: Finely reticulate, glossy, without pilosity; anterior face mostly straight; summit rounded; posterior face mostly straight. Gaster: Very finely striate, no pubescence, few short setae along membranes. Fore femur: Swollen. Mid tibia: Without erect setae, with very sparse, indistinct, flat-lying setae without bristles inside. In dorsal view. Head: Sides, posterior half straight; parallel; anterior half slightly convex, tapering to the front; vertex flatly convex, widely rounded corners; scape without erect setae; frontal carinae wider than half HW; frontal area indistinct, max HW posterior to eye centre; mandibles with many fine teeth. Clypeus: Coarsely striate longitudinally, without pubescence, carina replaced with groove; anterior margin convex, narrow, projecting. In front or rear view. Node: Wide, summit widely bidentad, without setae.

Minor worker. Whole ant varies from black with patches of red or red brown to occasionally all red. In Lateral view. Head: Side, glossy, finely reticulate with sparse, short, flat-lying setae; vertex with a few long setae; underside of head without setae. Mesosoma and node without erect setae or pubescence. Pronotum and mesonotum humped forming even convexity higher than metanotum. Metanotum: Deep wide trough with convex base; prominent spiracles pointing upward, placed near level of dorsum. Propodeum: Elevated, high, humped, evenly convex; angle well rounded; declivity mostly straight; ratio dorsum/declivity approximately 1; spiracle placed midway between dorsum and coxa, pointing rearward, surrounded by glossy, finely reticulate integument. Node: Anterior face lower half straight, upper convex; summit rounded; posterior face straight. Gaster: Microscopically striate. Fore femur: Swollen. Mid tibia: Sparse short, fine, adpressed setae, without bristles inside. In dorsal view. Head: Sides, flatly convex, tapering to front; vertex and angles uniformly convex; scape without erect setae, with indistinct adpressed setae. Frontal carinae short, very wide apart; mostly diverging; frontal area indistinct; max HW at eye centre. Clypeus: Wide, without truncation, few setae on margins, glossy, finely punctate-reticulate; carina distinct; anterior margin convex. In front or rear view. Node: Summit flatly convex, wide, without setae.

*Measurements*

HW 0.90-1.60 mm, HL 1.00-1.70 mm, PW 0.65-1.20 mm, TL 0.90-1.10 mm.

### Remarks

Wheeler (1934) described the subspecies *coloratus* based on "smaller average size and different colour pattern" and admitted that it was "only a slight variant of the typical form." Forel (1913) described the subspecies *lysias* as "differing in head shape from *C. gasseri* but otherwise identical with the type". Forel (1902) established the subspecies *obtusitruncatus* based on slight differences in head and mesosoma shape, sculpturing and colour, with the minor worker "having a shorter head and more convex pro-mesonotum, with the rest identical" to the typical form. We can find little to support the retention of any of these subspecies because the differences are trivial. *Camponotus gasseri* specimens collected at Beerwah, Queensland were light brown and smaller than those collected at Glen Osmond, South Australia as shown in Fig. 11. The stated differences in major workers are of little value in diagnosing these forms as they seem to be based on allometric variation within this caste rather than species-level differences.

*Camponotus gasseri* minor workers are often observed foraging on trunks of eucalypts in the Adelaide metropolitan area. On 20 Jan 1999, AJM when watching the removal of a large live *Eucalyptus camaldulensis* Dehnh at Glen Osmond, a south-eastern suburb of Adelaide, collected a sawn off log which housed a colony of *C. gasseri*. The diameter of the log was 120 mm and the ants' entrance was nearly 2 mm in diameter, at the junction of a dead offshoot of the log. On cutting open the log, 1142 workers, three dealate queens, one alate male and numerous eggs and naked larvae were found. The volume of the gallery, measured by filling it with water, was 125 ml. About 10 ml of frass resembling sawdust was also taken from the gallery. The gallery appeared to have been excavated by termites (determined by examination of the frass, P. Gleeson, pers. comm. 1999) and was located in the central heart wood and extended for about 300 mm, with the entrance tunnel about equidistant from each end. The width of the main gallery was about 10 mm diameter at the centre. Most of the ants were jet black with a little red at the anterior head, the amount of red being variable. In a few individuals the black was replaced by yellow-brown.

Wheeler (1934) described nests of *C. gasseri* near Perth, WA in branches of varying sized *Leptospermum* spp., *Acacia* spp., *Eucalyptus* spp and *Callitris* spp. Most of the specimens of *C. gasseri* examined here have been collected while the ants were foraging on vegetation, except for one collection from a pitfall trap and one from leaf litter and those collected from the sawn off log described above.

### *Camponotus howensis* Wheeler
(FIGS 12, 13)

*Camponotus (Colobopsis) howensis* Wheeler 1927: 152.

*Types examined:* Nine minor workers from Lord Howe Island, A. M. Lea (MCZ).

*Other material examined:* New South Wales: Lord Howe Island, Erskine Valley, 1966, RWT (ANIC); Lord Howe Island, Middle Beach Track, 2000, AJM & PJF (SAMA).

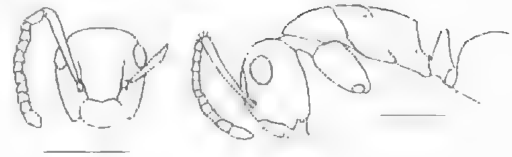
*Worker diagnosis*

Mandibles in major workers with distinct rugae superimposed over shallow fovae, rugae covering the entire dorsal surface of mandible. A few long, erect setae on head and gaster, none elsewhere. In lateral view, dorsal surfaces of pronotum, mesonotum and propodeum form a continuous weakly convex surface; posterior propodeal face slightly concave (Fig. 12).

*Worker description*

Major worker. In lateral view. Red brown, gaster generally darker, limbs similar in colour but with tarsi and tibiae slightly lighter. Head: Side with no erect setae; posterior glossy, smooth; anterior sharply truncated, anterior striations extending from truncation one/third distance to eye; vertex with few long setae; underside of head without erect setae, with very sparse, short, flat-lying setae. Mesosoma: Without erect setae. Pronotum and Mesonotum: Evenly convex. Metanotum: Wide trough, spiracle well below dorsum. Propodeum: Dorsum evenly curved; angle, rounded; declivity slightly concave, ratio dorsum/declivity approximately 1; spiracle well forward of declivity, closer to coxa than dorsum surrounded by indistinctly reticulate, glossy integument, without pilosity. Node: Without setae, anterior face lower half, straight, upper half evenly convex; summit blunt; posterior face straight. Gaster: Glossy indistinctly striate. Fore femur: Swollen. Mid tibia: Without erect setae, with sparse, flat-lying pubescence, without bristles inside. In dorsal view. Head: Nearly rectangular, sides straight, parallel; vertex straight; angles blunt; scape with very sparse, short, flat-lying setae. Frontal carinae mostly straight, diverging; posterior very wide. Frontal area, very small, depressed. Clypeus sides bordered by sharp ridge, narrow, widest at truncation; sides nearly straight, tapering anteriorly, grossly ridged longitudinally, similar to cheeks; three fourths of clypeus anterior to truncation. Anterior head comprising clypeus, mandibles and cheeks lying on flat circular plane; max HW at eye centre; eyes oval. Clypeus: Without erect setae, carina present, among striations; anterior margin narrow, projecting, evenly convex. In front or rear view. Node: Summit wide, slightly indented, without setae.

Minor worker. Head: Red-brown to dark brown, limbs and antennae slightly lighter colour, anterior of head yellow brown, vertex with few setae; underside of head without erect setae. Mesosoma: Glossy, microscopically reticulate without pilosity. Pronotum: Anterior and posterior thirds straight, centre third convex. Mesonotum: Mostly straight, slightly raised above pronotum and propodeum. Metanotum: Slight ridge, spiracle near middle of side. Propodeum: Dorsum straight to flatly convex; angle abrupt; declivity concave; ratio dorsum/declivity about 1.5; spiracle situated midway between dorsum and coxa surrounded by glossy microscopically reticulate integument. Node: Without pilosity; anterior face lower half straight, convex above; summit sharp; posterior face straight. Gaster: Finely striate. Fore femur: Swollen. Mid tibia: With indistinct sparse, short, flat-lying setae, without bristles inside. In dorsal view. Head: Sides straight, slightly tapering to the front, vertex and angles forming an even convexity; scape with indistinct, sparse, short, flat setae; frontal carinae diverging widely; frontal area indistinct, diamond shaped; max HW just posterior to eye centre. Clypeus: Glossy, finely reticulate, few sparse, erect setae; carina feeble; anterior margin convex, wide, projecting. In front or rear view. Node: Summit wide, sometimes indented, without setae.



Figs 12, 13. *Camponotus howensis*. 12. Minor worker, head and mesosoma. 13. Known distribution. Scale bars = 1 mm.

*Measurements*

PW 0.90-1.06 mm, HT 1.06-1.28 mm, EL 0.44-0.45 mm, HW 1.31-1.64 mm, HL 1.48-1.82 mm, CAR W 0.63-0.89 mm, CLY W 0.60-0.63 mm; TL 0.95-1.15 mm, NW 0.48-0.55 mm.

## Remarks

Wheeler (1927) described *Camponotus howensis* based on minor workers from Lord Howe Island. His description includes comparisons with a number of species from nearby Pacific islands but makes no reference to mainland Australian species such as *C. macrocephalus*. A more recent collection from Lord Howe Island by RWT includes both major and minor workers, minors of which match Wheeler's types. The specimens from Lord Howe Island are very similar to mainland specimens placed in *C. macrocephalus*. They differ in having the dorsal surface of the mandibles of major workers sculptured with longitudinal rugae superimposed over shallow fovae. The mandibles in *C. macrocephalus* are smooth with similar fovae and with, at most, weak rugae along the anterior (the region away from the head capsule) one-half or less. Additionally, the sculpturing on the anterolateral region of the head between the eye and the base of the mandible in major workers of *C. howensis* tends to be less extensive and weaker than the sculpturing found in *C. macrocephalus*. Finally, the colour of the Lord Howe Island material (all castes) is consistently dark brown while mainland material varies from yellow-brown to dark brown. No significant differences could be found between the minor workers from these regions. Based on this, these two taxa are treated as distinct with an acknowledgment that they are very closely related and may well prove to be conspecific.

*Camponotus janeti* Forel
(FIGS 14, 15)

*Camponotus janeti* Forel, A. 1895b: 417.
*Camponotus (Myrmamblys) janeti* Forel 1914: 271 Combination
*Camponotus janeti* Emery 1925: 138.
*Type examined*: Major and minor workers labelled "Typus from Queensland, Mackay." Box 174 (GMNH, ANIC)

*Other material examined:* Queensland: Cairns Parklands, 1975, BBL (ANIC); Mackay, 1949, TG (ANIC).

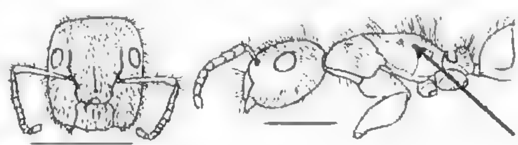
*Worker diagnosis*

Mesosoma low and long in profile with plentiful long, erect setae. Head, including underside, and scapes with plentiful long, erect setae (Fig. 14).

*Worker description*

Major worker. Very dark brown to black all over except red teeth; red brown antennae, lighter limbs. In lateral view. Head: Side glossy, finely reticulate, finely punctate with plentiful mid length setae (about 0.2 mm long), vertex with plentiful erect setae and no pubescence; underside of head with plentiful short and long, erect setae. Pronotum: Uniformly flatly convex, dorsum with plentiful mid length erect and few flat-lying setae. Mesonotum: Flatly convex, dorsum with plentiful erect setae; sides reticulate, more strongly below than above. Metanotum: Indistinct. Propodeum: Dorsum with plentiful erect setae, uniformly convex; sides reticulate, more strongly below than above; angle widely rounded; declivity straight; ratio dorsum/declivity approximately 1; spiracle projecting rearward, well forward of declivity, and midway between coxa and dorsum, surrounded by erect and flat-lying setae. Node: With long, erect and short, flat-lying setae; anterior face, lower half straight, upper convex; summit blunt; posterior face, lower half, straight upper half convex. Gaster: Finely striate. Fore femur: Swollen. Mid tibia: Plentiful upstanding long setae, without bristles inside. In dorsal view. Head: Very finely densely punctate with few coarse punctations; sides straight, slightly tapering to front; vertex convex; scape with erect and flat-lying setae. Frontal carinae wide, strongly diverging at front, posterior half straight; frontal area small, diamond shaped, smoother than surroundings; max HW just posterior to eye centre. Clypeus: Without striations, scarcely truncated, sides widest at centre, less than one third HW, with few erect setae and no pubescence, without carina; anterior margin projecting, straight, narrow. In front or rear view. Node: Summit wide, outer thirds convex, centre third straight or slightly concave; with plentiful long setae.

Minor worker: In lateral view. Very dark brown to black all over except red mandibles, lighter antennae, darker red brown limbs. Head: Side glossy, finely reticulate with plentiful mid length and longer setae.



Figs 14; 15. *Camponotus janeti*. 14. Minor worker, head and mesosoma. Mesosoma is low and long. 15. Known distribution of *C. janeti*. Scale bars = 1 mm.

vertex with plentiful, erect setae, no pubescence; underside of head with plentiful longish erect setae. Pronotum: Rounded lateral margin, uniformly flatly convex; dorsum with plentiful erect and few flat-lying setae. Mesonotum: Flatly convex, dorsum with plentiful long erect setae. Metanotum: A slight depression. Propodeum: Dorsum with plentiful erect setae of various lengths; uniformly convex, making whole mesosoma evenly convex; sides more strongly reticulate below than above, angle widely rounded; declivity flatly convex; ratio dorsum/declivity about 1.5; spiracle projecting outward, well forward of declivity and midway between coxa and dorsum; surrounded by erect and flat-lying setae. Node. Long, with long erect and short, flat-lying setae; anterior face lower half straight convex above; summit rounded with weak ridge; posterior face lower half straight, upper half convex. Gaster: Glossy slightly finely striate. Fore femur: Swollen. Mid tibia: With plentiful coarse, mostly decumbent setae, without bristles inside. Dorsal view. Head: Very finely and densely punctate, sides straight, strongly tapering to front; vertex convex, angles widely rounded; scape with erect and flat-lying setae; frontal carinae wide, strongly diverging; frontal area distinctly diamond shaped, depressed; max HW at eye centre; eyes close to corners. Clypeus: Wide, with few short decumbent setae; carina distinct; anterior margin projecting, mostly convex. Front or rear view. Node: Summit wide, convex, with plentiful long setae.

*Measurements*

HW 0.95-1.70 mm, HL 1.00-2.00 mm, PW 0.70-1.15 mm, HT 0.75-1.00 mm, EL 0.25-0.35 mm, CAR W 0.50-0.90 mm, CLY W 0.50-0.65 mm, TL 0.90-1.20 mm.

## Remarks

This rare species has been collected only a few times from northern Queensland. The only biological notes refer to one collection from a tree in parkland.

## *Camponotus janforrestae* sp. nov.
(FIGS 16, 17)

*Holotype*: One minor worker pinned. Queensland, Cairns, Parklands, 2/8/75, B. B. Lowery (ANIC).

*Other material examined:* Queensland: St. George, near Balonne River, 1966, BBL (ANIC); St. George, Balonne River bank, 1966, BBL (ANIC).

*Worker diagnosis*

Whole ant (with the exception of the funiculus) clothed in erect setae. On mesosoma setae vary from short to long. Dorsal surface of propodeum strongly convex and dome-like (Fig. 16).

*Worker description*

Minor worker. All black except for dark brown teeth and limbs. In lateral view. Head: Side with few erect setae, without flat-lying pubescence, glossy, smooth; vertex with plentiful long setae; underside of head with plentiful long and short setae. Pronotum: Evenly convex with plentiful erect setae of various lengths. Mesonotum: Flatly convex with plentiful setae. Metanotum: Deep trench, with spiracles projecting up, apertures below level of dorsum. Propodeum: Plentiful long setae, glossy, dorsum domed, nearly circular; angle rounded; declivity mostly straight, spiracle projecting outward, surrounded by slightly punctate integument with flat-lying and erect setae. Node: Thick with plentiful long erect setae; anterior face short upright; summit blunt; posterior face lower half straight; upper convex. Gaster: Glossy, hairy. Fore femur: Dark red brown, swollen. Mid tibia: With plentiful long and a few short, erect setae, without bristles on inside. In dorsal view. Head: Sides straight, strongly tapering to front, posterior angles and vertex forming even convexity, scape with plentiful long and short, erect setae. Frontal carinae wide, diverging to rear, not converging; posterior width twice anterior; frontal area elongated diamond, small; max HW posterior to eye centre. Clypeus: Wide, glossy, smooth, without flat-lying pubescence, with few erect, long setae; carina indistinct; anterior margin lateral quarters projecting forward, median half indented between two teeth. In front or rear view. Node: Summit flat, between convex lateral thirds, with plentiful long setae of varying length.

*Measurements*

HW 1.6 mm, HL 1.8 mm, PW 1.2 mm, HT 1.25 mm, EL 0.35 mm, TL 1.7 mm.

*Etymology*

Named after J. A. Forrest OAM, SAM, Adelaide.

## Remarks

This rare species has been collected only three times. The limited biological information indicates that it was common on box and gum trees on black soil and was foraging all afternoon at St George. It is highly distinctive and unlikely to be confused with other members of this species group.

## *Camponotus mackayensis* Forel
(FIGS 18, 19)

*Camponotus reticulatus mackayensis* Forel 1902: 506.

*Camponotus (Myrmamblys) reticulatus mackayensis* Emery 1925: 139 Subgeneric assignment.

*Type examined*: Major and minor workers, labelled "typus", Box 174 (GMNH, ANIC).

*Other material examined*: Northern Territory: Caiman Ck, 1977, TAW (ANIC); Darwin, 1961, LW (ANIC), Howard Springs, 1951, WLB (ANIC); Kakadu NP, 1994, BBL (SAMA); Smith Point, 1977, RAB (ANIC); Smith Point, 1977, TAW (ANIC); Smith Point, 5 mi. E by S, 1977, TAW (ANIC); Wangi Falls, 1994, BBL (SAMA); Wessel I., Rimbiji I., 1977, TAW (ANIC). Queensland: Cairns, 1962, RWT (ANIC); Cairns Edge Hill, 1975, BBL (ANIC); Edge Hill (ANIC); Lake Eacham NP, 1972, RWT (ANIC); Mingela, 1 km E, 1977, BBL (ANIC); Missionary Bay, 1977, RWT (ANIC).

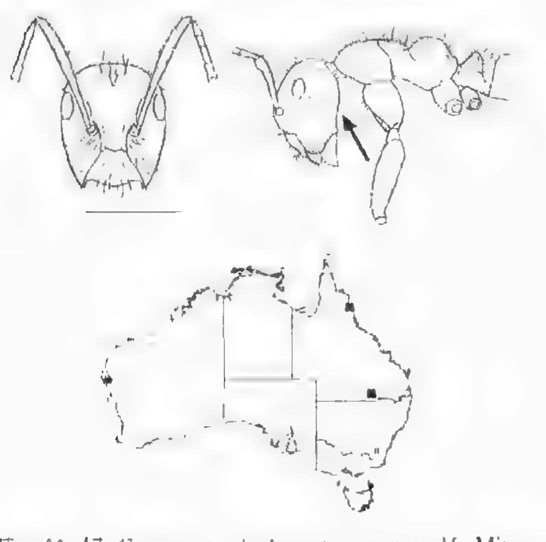
*Worker diagnosis*

Dorsal surface of propodeum with shallow concavity. Sparse to plentiful erect, long setae on most surfaces, including scape (Fig. 18).

*Worker description*

Major worker. In lateral view. Head: Red brown, anterior half coarsely punctate with plentiful short, whitish, sub-erect setae, posterior half smooth, glossy, with few shallow punctations; scape brown, funiculus lighter red brown; vertex with plentiful short setae, few shallow punctations; underside of head with short setae. Pronotum: Red brown, lighter than mesonotum, evenly convex, dorsum with few long and short setae. Mesonotum: Brown, evenly convex, dorsum with plentiful short setae. Metanotum: Distinct, wide, shallow groove. Propodeum: Brown, dorsum with few long setae, anterior dorsum marked by narrow ridge, otherwise straight; angle abrupt; declivity straight; ratio dorsum/declivity approximately 1; deeply striate near spiracle. Node: With few long setae, brown; anterior face lower half straight, upper convex; summit blunt; posterior face straight. Gaster: Brown, finely striate. Fore coxa: Mostly red brown with some yellow. Fore femur: Red brown, swollen. Fore tibia and tarsus: Red brown. Mid tibia: Outside with sparse flat-lying, short setae, without bristles inside. In dorsal view. Head: Sides straight tapering to front; vertex straight, slightly concave in some views; frontal area small, depressed and extended longitudinally; frontal carinae nearly parallel, anterior half diverging, posterior half wide; plentiful short, sub-erect setae on clypeus and cheeks. Clypeus: Oval shaped, widest at truncation, coarsely punctate, similar to cheeks; anterior margin projecting, convex, narrow, less than half head width at mandibles. Front or rear view. Node: Summit wide, straight, with few long setae.

Minor worker. In lateral view. Head: Red brown, side glossy with sparse short flat setae; scape red brown; funiculus lighter red brown; vertex with few long setae, underside of head without erect setae, with sparse, short, flat-lying setae. Pronotum: Red brown, lighter than mesonotum. Pronotum and mesonotum: Even convexity with few, very long setae. Metanotum: Distinct vee. Propodeum: Brown, dorsum with few scattered setae, anterior dorsum inclined upward to ridge, then shallow concavity to



Figs 16, 17. *Camponotus janforrestae* sp. nov. 16. Minor worker, head and mesosoma. Underside of head with erect setae. 17. Known distribution. Scale bar = 1 mm.

Figs 18, 19. *Camponotus mackayensis*. 18. Minor worker, head and mesosoma. Dorsum of propodeum is concave. 19. Known distribution. Scale bars = 1 mm.

widely rounded angle; declivity mostly straight; ratio dorsum/declivity about 1.5; glossy, deeply striate near spiracle. Node: Brown with few long setae, without pubescence; anterior face mostly straight, summit rounded; posterior face straight. Gaster: Brown, glossy, finely striate. Fore coxa: Mostly red brown with some yellow. Fore femur: Swollen. Tarsus: Red brown. Mid tibia: Red brown with sparse, flat-lying setae, without bristles inside. In dorsal view. Head: Sides, anterior half tapering to front; vertex flatly convex between widely rounded corners; scape sometimes with few long setae; frontal carinae diverging wide; frontal area depressed; max HW posterior to eye centre; five coarse teeth visible. Clypeus: Glossy with few long and short, scattered flat-lying setae; carina indistinct; anterior margin convex, projecting. In front or rear view. Node: Summit wide, straight with few long setae.

*Measurements*

PW 0.80-1.05 mm, HT 0.7-1.15 mm, HW 1.00-1.15 mm, HL 1.00-1.70 mm, CAR W 0.8 mm, CLY W 0.4-0.45 mm, TL 0.8-1.0 mm.

## Remarks

Workers of this species have been found on trees as well as the ground in rainforests, mangrove and savannah woodland. All known nests have been found in dead twigs and branches.

## *Camponotus macrocephalus* (Erichson)
(FIGS 20, 21)

*Formica macrocephala* Erichson 1842: 259.
*Camponotus (Colobopsis) fictor* Forel 1902: 508 Synonym Shattuck and McArthur 1995: 121.
*Camponotus fictor augustulus* Viehmeyer 1925: 145 New Synonym.
*Colobopis rufifrons semicarinata* Forel, 1895b 118 New Synonym.
*Camponotus (Colobopis) semicarinatus* Forel 1902: 508 Combination.

*Types examined: Camponotus fictor.* Major and minor workers labelled "Typus from Newcastle New South Wales." Box 175 (GMNH). *Camponotus fictor augustulus.* Major and minor workers labelled "Typus from Trial Bay, New South Wales" (ANIC). *Camponotus semicarinatus.* Major and minor workers labelled "Typus from Mackay, Queensland" (GMNH).

*Other material examined:* Australian Capital Territory: Blundell's Farm, 1955, TG (ANIC); Brindabella, 1933, TG (ANIC); Brindabella Ra., 1930, TG (ANIC); Canberra Sutton Rd, 2025, TG (ANIC); Kowen, 1932, TG (ANIC); Lees Spring, 1930, TG (ANIC); Lees Spring, 1931, TG (ANIC); Uriarra, 1931, TG (ANIC); Yarralumla, 1976, BBL (ANIC). New South Wales: Braidwood Rd, 1937, TG (ANIC); Burns Bay, Lane Cove, 1959, BBL (SAMA); Ebor, 1973, BBL (ANIC); Gerroa, 1962, BBL (ANIC); Kiandra, 1960, EFR (ANIC); Nerriga Braidwood Nowra Rd, 1937, TG (ANIC); Newcastle, JCL (ANIC); Pine Ck State Forest, 1957, TG (ANIC); Pymble, 1956, BBL (ANIC); Pymble, 1944, JMc (ANIC); Springwood, 1965, BBL (ANIC); Tumbulgum, 1962, BBL (ANIC); Tumut, 1962, BBL (ANIC). Queensland, Brisbane, JDM (Curtin); Brisbane, 1948, RAP (ANIC); Bundaberg, 1968, JJD (ANIC); Bundaberg, JJD (ANIC); Cairns, 1975, BBL (ANIC); Cairns, 1975, BBL (ANIC); Cairns, 30 mi. N, 1966, RWT (ANIC); Giru Haughton R., 1980, RWT (ANIC); Lamington Plateau, Nuptial Flight, 1999, RE (SAMA); Missionary Bay, Hinchinbrook I., 1977, RWT (ANIC). South Australia: Littlehampton, 1995, JT (SAMA); Lucindale, Feu (SAMA). Tasmania. Asbestos Ra., 1991, BBL (SAMA); Bakers Beach, 1994, BBL (SAMA); Big River, 1991, BBL (SAMA); Bridport, 1995, BBL (SAMA); Dulverton, 1995, BBL (SAMA); Emita Flinders I., 1991, BBL (SAMA); Epping Forest, 1993, BBL (SAMA); Flinders I., Mt Strezlecki, 1991, BBL (SAMA), Freycinet Peninsula, BBL (SAMA); Isthmus Bay, 1992, BBL (SAMA); Low Head, 5 km E, 1992, BBL (SAMA); Mt William, 1993, BBL (SAMA); North Bruny I., 1992, BBL (SAMA); Port Sorell, 4 km S, 1992, BBL (SAMA); Sassafras, 1993, BBL (SAMA); Seymour, 1994, BBL (SAMA). Victoria: Greensborough, JMc (ANIC); Loongatha, 1957, BBL (ANIC); Portland, 1958, JMc (ANIC).

*Worker diagnosis*

Mandibles in major workers smooth, with shallow fovae, rugae weak and limited to anterior region of dorsal surface of the mandible. Few long, erect setae on head and gaster, none elsewhere. In lateral view, dorsal surfaces of pronotum, mesonotum and propodeum form a continuous weakly convex surface, the posterior propodeal face mostly straight (Fig. 20).

*Worker description*

Major worker. In lateral view. Yellow brown, gaster sometimes darker, limbs, especially coxa very much lighter than mesosoma. Head: Side with no erect setae, anterior sharply truncated; posterior glossy, smooth, anterior striations extending from truncation nearly half way to eye; vertex with few long setae; underside of head without erect setae, with very sparse short, flat lying setae. Mesosoma: Without erect setae. Pronotum and Mesonotum: Evenly convex.

Metanotum: Wide trough, spiracle well below dorsum. Propodeum: Dorsum evenly curved, angle rounded, declivity mostly straight: ratio dorsum/declivity, approximately 1; spiracle well forward of declivity, closer to coxa than dorsum, surrounded by indistinct reticulate integument, glossy, without pilosity. Node: Without setae, anterior face lower half straight, upper evenly convex; summit blunt; posterior face straight. Gaster: Glossy, indistinctly striate. Fore femur: Swollen. Mid tibia: Without erect setae, with sparse, flat-lying pubescence, without bristles inside. In dorsal view. Head: Nearly rectangular; sides straight, parallel; vertex straight, angles blunt; scape with very sparse, short, flat-lying setae. Frontal carinae mostly straight, diverging, posterior very wide. Frontal area, very small, depressed; clypeus sides bordered by sharp ridge, narrow, widest at truncation, sides nearly straight, tapering anteriorly, grossly ridged longitudinally, similar to cheeks, three fourths of clypeus anterior to truncation. Anterior head comprising clypeus, mandibles and cheeks lie on flat circular plane; max HW at eye centre; eyes oval. Clypeus: Without erect setae, carina present within striations; anterior margin narrow, projecting, evenly convex. In front or rear view. Node: Summit wide, slightly indented, without setae.

Minor worker. Head: Brownish yellow to brown, limbs and antennae more yellowish, much lighter than mesosoma; side of head, mesosoma, node yellow brown; vertex with few setae; underside of head without erect setae. Mesosoma: Glossy, microscopically reticulate, without pilosity. Pronotum: Anterior and posterior thirds straight, centre third convex. Mesonotum: Mostly straight, slightly raised above pronotum and propodeum. Metanotum: Slight ridge; spiracle near middle of side. Propodeum: Dorsum straight to flatly convex, angle abrupt; declivity nearly straight, ratio dorsum/declivity about 1.5; spiracle situated midway between dorsum and coxa, glossy, surrounded by microscopic reticulation. Node: Without pilosity, anterior face lower half straight, convex above; summit sharp; posterior face straight. Gaster: Finely striate. Fore femur: Swollen. Mid tibia: With indistinct, sparse, short, flat-lying setae, without bristles inside. In dorsal view. Head: Sides straight, slightly tapering to front; vertex and angles form even convexity; scape with indistinct, sparse, short, flat setae; frontal carinae wide, diverging; frontal area indistinct, diamond shaped; max HW just posterior to eye centre. Clypeus: Glossy, finely reticulate, few sparse, erect, setae, carina indistinct; anterior margin, convex, wide, projecting. In front or rear view. Node: Summit wide, sometimes indented, without setae.

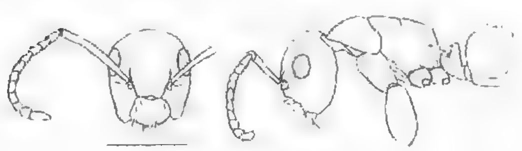
*Measurements*

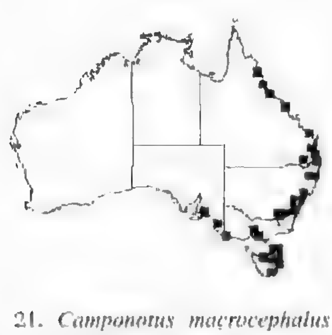
PW 0.7-1.2 mm, HT 0.8-1.25 mm, EL 0.3-0.4 mm, HW 0.95-1.7 mm, HL 1.1-1.9 mm, CAR W 0.5-0.8 mm, CLY W 0.5-0.6 mm, TL 0.95-1.0 mm, NW 0.35-0.65 mm.

## Remarks

Forel (1902) distinguished *semicarinatus* from *macrocephalus* (as *fictor*) by differences in the shape of the head, propodeum and petiolar node and in having the sculpturing on the truncated portion of the clypeus "more clearly lengthwise and not wrinkled-reticulate as in the case of *semicarinatus*". Viehmeyer (1925) described the subspecies *angustulus* as having "head of the major worker noticeably narrower than in the type, the truncate surface of the anterior head less sharply delineated and less concave, and the longitudinal grooves of the head and clypeus much stronger". However, the currently available material shows considerable variation in all of these characters and we can find no justification for recognising the subspecies separately from *C. macrocephalus*. For separation from the closely related *C. howensis*, see **Remarks** under that species.

*Camponotus macrocephalus* is generally found nesting in branches of trees and shrubs in eastern Australia.





Figs 20, 21. *Camponotus macrocephalus*. 20. Minor worker; head and mesosoma. Dorsum of mesosoma is mostly straight. 21. Known distribution of *C. macrocephalus*. Scale bar = 1 mm.

*Camponotus sanguinifrons* Viehmeyer
(FIGS 2, 22, 23)

*Camponotus (Colobopsis) sanguinifrons* Viehmeyer 1925: 143.

*Type examined*: Major and minor workers labelled "Typus," from Trial Bay, New South Wales, Box 165/3 (ZMB).

*Other material examined*: New South Wales: Leppington, 1966, EK (ANIC); Mt Warning, 1964, BBL (ANIC); Tumut, 1962, BBL (ANIC); Leslie Dam, 1997, AJM & RE (SAMA); Tumut, 1962, BBL (ANIC). Northern Territory: Kakadu NP, 1992, BBL (SAMA). Queensland: Mackay, 1972, BBL (ANIC); Mingela, 1 km E, 1997, BBL (SAMA); Mt Tozer, 3 km ENE, 1986, JCC (ANIC); Mackay, GT (ANIC).

*Worker diagnosis*

Minor worker with a few long, erect setae on underside of head, few more on gaster and none elsewhere. Dorsal surface of propodeum about three times as long as declining surface. Major differs greatly from minor. In major worker, anterior regions of head clothed in plentiful short, clavate setae (Fig. 2) particularly on and near truncation; absent from posterior regions; few long setae on underside of head, coxa and gaster (Fig. 22).

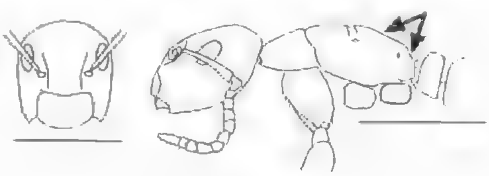
*Worker description*

Major worker. In lateral view. Head: Posterior dark brown, anterior red; posterior without pilosity, anterior with dense, fine, short, white, clavate setae (Fig. 2) especially on cheeks and clypeus; antennae red brown; underside of head with few long setae. Mesosoma and node: Dark brown without pilosity, glossy, finely striate. Pronotum: Anterior quarter straight, next quarter rounded, then flatly convex. Posterior half of pronotum, mesonotum, metanotum and dorsum of propodeum form uninterrupted gentle curve. Metanotum: Wide, marked by two transverse sutures. Propodeum: Angle about 150°; declivity mostly straight; ratio dorsum/declivity about 1.5. Node: Anterior face lower half straight, otherwise convex; summit rounded; posterior face straight, inclined forward. Limbs: Lighter coloured than mesosoma, fore femur swollen. Mid tibia: With short, sparse, flat-lying setae, without bristles inside. In dorsal view. Head: Sides straight, parallel; vertex mostly straight, scape with indistinct, flat, short, sparse setae; frontal carinae wide, short, straight, diverging behind; anterior head truncated, clypeus mandibles and cheeks forming flat circular area coarsely punctate with few coarse longitudinal striations and central keel; plentiful short, erect, stubble-like, clavate setae; clypeus lateral margins widest at centre of circular area; frontal area extended laterally at truncation. Clypeus: Anterior margin well posterior to mandible insertions, straight, short. In front or rear view. Node: Summit flat, wide.

Minor worker. In lateral view. Dark brown, limbs, anterior head and antennae a little lighter coloured. Head: Side glossy without pilosity, finely striate; vertex with a few long setae, underside of head without pilosity. Mesosoma: Without pilosity, finely striate, reticulate. Pronotum: Anterior half convex, posterior half straighter. Mesonotum: Anterior and posterior sixths inclined, centre flatly convex. Metanotum: Shallow trough, spiracle well below dorsum. Propodeum: Dorsum anterior quarter inclined upward, otherwise straight and sloping downward; angle rounded 135°; declivity upper half straight, lower half strongly concave; ratio dorsum/declivity approximately 3; spiracle situated well forward of declivity and midway between dorsum and coxa. Node: Without pilosity, anterior and posterior faces parallel, anterior face short, straight; summit sloping upward rounded; posterior face straight, longer than anterior. Gaster: Finely striate, scattered upstanding setae without visible pubescence. Fore femur: Swollen. Mid tibia: Sparse, fine, flat-lying setae, without bristles inside. In dorsal view. Head: Sides straight, tapering slightly to front; vertex flat with rounded corners; scape with indistinct, sparse, fine, flat-lying setae; frontal carinae short, wide; frontal area indistinct; max HW near eye centre. Clypeus and cheeks: Finely reticulate with few setae; carina distinct posteriorly; anterior margin projecting, evenly convex, wide. In front or rear view. Node: Summit straight; without pilosity.

*Measurements*

PW 0.45 – 0.55 mm, HT 0.55 – 0.65 mm, EL 0.20-0.22 mm, HW 0.75 - 1.10 mm, HL 0.85 – 1.40 mm.



Figs 22, 23. *Camponotus sanguinifrons*: 22. Minor worker, head and mesosoma. Dorsum of propodeum is longer than declivity. 23. Known distribution. Scale bars = 1 mm.

CAR W 0.4 mm, CLY W 0.38 mm, TL 0.72 -0.75 mm, NW 0.2 - 0.25 mm.

### Remarks

In this species the major workers and queens possess plentiful distinctive short, clavate setae (Fig. 2) on the anterior head. Setae on the anterior head of minor workers are sparse, longer, uniform diameter and not clavate. (Clavate setae resemble a forest of miniature matches with enlarged extremities.) Such clavate setae are uncommon in *Camponotus* although Donisthorpe (1948) refers to similar clavate setae in *Camponotus* (*Colobopsis*) *excavatus* from Maffin, West Irian.

AJM and RE collected an alate female at Leslie Dam, Eatonsville, NSW at 10 p.m. on 29 Nov. 1997. This suggests that nuptial flights of this species might occur near the last week in November.

### *Camponotus vitreus* (Smith)
(FIGS 24, 25)

*Formica vitrea* Smith 1860: 94.
*Prenolepsis adlerzii* Forel 1886: 209; Forel 1895: 458 Synonym.
*Camponotus (Colobopsis) vitreus*: Emery 1893: 225 Combination.
*Camponotus vitreus*: Forel 1895a: 455.
*Camponotus vitreus*: Viehmeyer 1916: 160.
*Camponotus vitreus*: Emery 1925: 148.
*Camponotus vitreus*: Karavaiev 1933: 319.

*Material examined*: Northern Territory: Darwin, 10 mile Jungle, WCC (SAMA); Darwin, Holmes Jungle, 1997, AJM (SAMA); Howard Springs, AS (SAMA); Howard Springs, 1951, WLB (ANIC); Litchfield, 1994, BBL (SAMA); Mt Brockman, Radon Ck, 1979, GBM (ANIC); Mt Gilruth, NE Gorge, 1979, GBM (ANIC). Queensland: Bamaga, 1983, JS (ANIC); Brisbane, JDM (Curtin); Cairns, 1970, DPIQ (DPIQ); Cairns, 1996, JBS (ANIC); Cairns, 1914, WMW (SAMA); Cairns, 20 km N, Cook Hwy, 1975, BBL (ANIC); Cairns, Lake Placid, 1975, BBL (ANIC); Cairns, Parkland, 1975, BBL (ANIC); Cape Tribulation, 1980, GBM (ANIC); Cape Tribulation, 2.5 km W, 1982, GBM (ANIC); Cardwell, 10 km NW, 1976, PJM (ANIC); Clump Point, 6 km W, 1971, RWT, JEF (ANIC); Cooktown Bot. Gdn., 1990, BBL (ANIC); Daintree, Cooper Ck, 1971, RWT, JEF (ANIC); Deeral Landing, 1975, BBL (ANIC); Edge Hill, 1971, BBL (ANIC); Etty Bay, 1980, GBM (ANIC); Goodna, 1956, BBL (ANIC); Hayman I., 1996, RSB (ANIC); Heathlands, 12 km SSE, 1992, IDN (ANIC); Hope Vale Mission, 15 km W by N, 1981, JEF (ANIC); Ingham, 1975, BBL (ANIC); Iron Ra., 1971, RWT, JEF (ANIC); Kuranda, 1914, AML, WMW (ANIC); Kuranda, 1919, FPD (SAMA); Kuranda, 1914, WMW (SAMA); Lake Eacham, 1972, RWT (ANIC); Lakefield, Laura, 1980, GBM (ANIC); Mackay, Tur (ANIC); Magnetic I., 1981, BBL (ANIC); Magnetic I., GFH (ANIC); Mareeba, 1937, TG (ANIC); Mareeba Clahesy R., 1937, TG (ANIC); Mission Beach, 1962, RWT (ANIC); Missionary Bay, Hinchinbrook I., 1977, RWT (ANIC); Mossman Gorge, 1966, RWT (ANIC); Mt Baird, 3.5 km SW by S, 1981, IDN (ANIC); Mt Cook NP, 1980, DHC (ANIC); Mt Coot-tha, 1961, BBL (ANIC); Mt Tozer, 3 km ENE, 1986, TAW (ANIC); Mt Webb, 1981, IDN (ANIC); Packers Ck nr Portland Roads, 1985, GBM, DJC (ANIC); Palm I., GFH (ANIC); Palmerstone NP, 1969, RWT (ANIC); Rounded Hill, 1 mile N, 1981, JEF (ANIC); Silver Plains, Massey Ck, 1979, BJW (ANIC); Somerset, 1976, EC (ANIC); Townsville, 1902, FPD (SAMA); Townsville, 1974, JAh (ANIC); Yarrabah Aboriginal Community, 1988, RWT (ANIC).

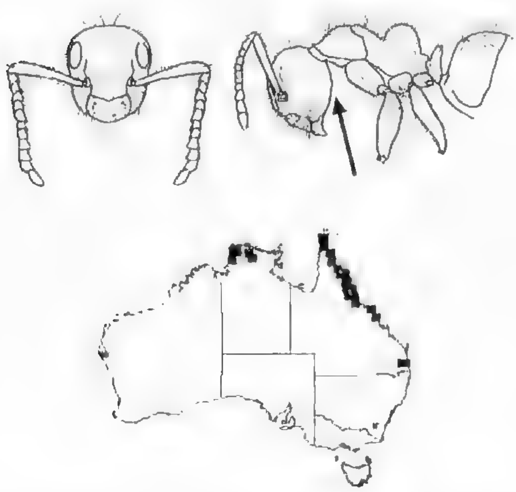
*Worker diagnosis*

Whole ant clothed in plentiful long erect setae except absent on most of underside of head. In lateral view, metanotal groove is depressed, mesonotum and propodeum form high, arched convexities (Fig. 24).

*Worker description*

Major worker. In lateral view. Dark red brown, limbs and funiculus lighter coloured, gaster darker. Head: Truncation rounded 135°; side glossy with sparse extremely short, adpressed setae, without erect setae; few long and short, erect setae on vertex and posterior head, absent on anterior head; underside of head without erect setae. Pronotum and mesonotum: Uniform semicircle scarcely marked by pro-mesonotal suture, plentiful long and short, erect setae and sparse flat-lying setae. Metanotum: Trough with distinct sloping sides; spiracle directed upward, aperture level with dorsum. Propodeum: Humped high, also forming semicircle, slightly flattened on top; angle near right angle, rounded; declivity straight above, concave below; ratio dorsum/declivity about 1.5; spiracle situated midway between coxa and dorsum, directed backward, surrounded by glossy surface with very sparse, short, fine setae. Node: Short longitudinally, few long setae, without pubescence, lower and upper halves of anterior face straight, separated by rounded 135° angle; summit sharp; posterior face mostly straight. Gaster: Glossy. Fore femur: Swollen. Mid tibia: With plentiful sub-erect setae, without bristles inside. In dorsal view. Head: Sides weakly convex, tapering to front; vertex straight; scape with plentiful distinct setae raised 45°; frontal carinae wider than half HW, more or less continuous with lateral margins of clypeus; frontal area elongated, diamond shaped, depressed; max HW at eye centre; five teeth. Clypeus slightly raised above cheeks and separated on sides by ridge; anterior third of clypeus, surrounding cheeks and mandibles form a truncated plane separated from surroundings by rounded angle without striations; sides of clypeus narrow, widest at truncation then tapering to front; glossy without pubescence, with one or two erect setae; without carina; anterior margin very narrow, projecting, convex. Front or rear view. Node: Summit straight sometimes widely indented, with plentiful, short, fine setae.

Minor worker. Lateral view. Dark red brown, limbs and funiculus lighter. Head: Side glossy with sparse, extremely short, adpressed setae; vertex with few long and short fine setae; underside of head without erect setae. Mesosoma: Similar to major worker except aperture of metanotal spiracle placed above dorsum. Node: Short longitudinally with few long setae, lacking pubescence; lower and upper halves of anterior face straight, separated by rounded 135° angle; summit sharp but not as sharp as major; posterior face mostly straight. Gaster: Slightly darker than head, glossy. Fore femur: Little lighter coloured than coxa, swollen. Mid tibia: Plentiful sub-erect, long, setae, lacking bristles on inside. Dorsal view. Head: Sides nearly straight, tapering to front; vertex convex, flattened at centre; scape with plentiful distinct setae raised 45°; frontal carinae wider than half HW; frontal area indistinct triangle; max HW at eye centre. Clypeus: Without truncation, finely punctate, anterior margin convex, projecting, very wide; sides of clypeus straight; glossy, without pubescence with few fine, erect setae; with indistinct carina. Front or rear view. Node: Summit wide, straight, with plentiful; short; fine setae, sometimes indented.



Figs 24, 25. *Camponotus vitreus*. 24. Minor worker, head and mesosoma. Underside of head lacks erect setae. 25. Known distribution of *C. vitreus*. Scale bar = 1 mm.

*Measurements*

HW 0.85-1.55 mm, HL 0.85-1.55 mm, PW 0.60-1.05 mm, HT 0.65-1.20 mm, CARW 0.45-0.85 mm, TL 0.80-0.95 mm.

## Remarks

*Camponotus vitreus* is confined to the tropics and is often seen foraging on tree trunks and on the ground in rain forest. Smith (1860) described this species from specimens collected by A. R. Wallace, at "Bachian, running in numbers up and down tree trunks, probably in search of Aphides" (the locality is now Batjan, Molucca Islands, Indonesia). Viehmeyer (1916) noted that in Singapore, *C. vitreus* "nests in thin bamboo, in rotten wood and in hollow branches of *Mangifera*. Females frequently on the lamp. One such caught female had raised 6 sterile females in a plaster nest". WCC collected specimens of *C. vitreus* from "a hole in a tree" near Darwin. Staff of the Quarantine Service, Department of Primary Industries, Queensland collected specimens of *C. vitreus* (vial Hy77) from a wooden window sill at Cairns, Qld on 5 June 1970. No attempt has been made here to determine the distribution of *C. vitreus* outside Australia. We have been unable to examine type material of *C. vitreus* and the concept accepted here is based on Smith's original description.

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# OBSERVATIONS ON THE DEVELOPMENT AND PARASITOIDS OF FERGUSONINA/FERGUSOBIA GALLS ON MELALEUCA QUINQUENERVIA (MYRTACEAE) IN AUSTRALIA

*By* K. A. DAVIES*, J. MAKINSON† & M. F. PURCELL†

## Summary

Davies, K. A., Makinson, J. & Purcell, M. F. (2001) Observations on the development and parasitoids of Fergusonina/Fergusobia galls on Melaleuca quinquenervia (Myrtaceae) in Australia. Trans. R. Soc. S. Aust. 125(1), 45-50, 31 May, 2001.
The gall-forming Fergusonina/Fergusobia association is being considered as a potential biocontrol agent of Melaleuca quinquenervia in Florida, where it has become a serious weed. This paper reports observations on the development of Fergusonina/Fergusobia galls on M. quinquenervia in coastal and sub-coastal south-eastern Queensland and northern New South Wales. The morphology of the gall and the relationship between gall size and numbers of developing cavities and insects are described. Nematodes were found in cavities containing first and second or early third stage fly larvae. Eight species of hymenoptera parasitoids were reared from galls.
Key Words: Galls, field surveys, Fergusonina, Fergusobia, Melaleuca quinquenervia, flies, nematodes, parasitoids, gall inquilines.

*Transactions of the Royal Society of S. Aust.* (2001), **125**(1), 45-50.

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## Summary

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The gall-forming *Fergusonina/Fergusobia* association is being considered as a potential biocontrol agent of *Melaleuca quinquenervia* in Florida, where it has become a serious weed. This paper reports observations on the development of *Fergusonina/Fergusobia* galls on *M. quinquenervia* in coastal and sub-coastal south-eastern Queensland and northern New South Wales. The morphology of the gall and the relationship between gall size and numbers of developing cavities and insects are described. Nematodes were found in cavities containing first and second or early third stage fly larvae. Eight species of hymenopteran parasitoids were reared from galls.


KEY WORDS: Galls, field surveys, *Fergusonina*, *Fergusobia*, *Melaleuca quinquenervia*, flies, nematodes, parasitoids, gall inquilines.

## Introduction

The obligate association between *Fergusonina* spp. (Diptera: Fergusoninidae) and *Fergusobia* spp. (Nematoda: Tylenchida: Sphaerulariidae) in galls on members of family Myrtaceae is amongst the most complex known (Taylor *et al.* 1996; Giblin-Davis *et al.* 2001). The fly/nematode association was first described by Currie (1937) and development of the nematode was further clarified by Fisher & Nickle (1968). The nematode has two types of life cycle, with a parthenogenetic generation followed by a heterosexual generation. In the latter, male and female nematodes develop to the adult stage in the plant gall, where young females are inseminated, and then enter the mature third stage larva of the female fly. They become parasites of the fly, growing and laying eggs in the haemolymph of the adult fly developing in the puparium. Juvenile nematodes hatch and some move into the fly ovaries. When the adult fly emerges from the gall, it deposits its eggs and juvenile nematodes within primordial leaf and flower bud tissues, where new galls develop and in which the parthenogenetic generation of the nematode occurs. Giblin-Davis (unpub. 2000) has preliminary evidence suggesting that in *M. quinquenervia* the nematode initiates gall formation before the fly eggs have hatched. The feeding activity of the fly larvae apparently leads to formation of the characteristic cavities within the gall (Currie 1937; Giblin-Davis unpub.). Associations between the nematode and fly appear to be species-specific (Giblin-Davis *et al.* 2001).

The 21 species of *Fergusonina* described from Australia are from *Eucalyptus* (Tonnoir 1937) with one species from India on *Syzygium* (Harris 1982). Most records of *Fergusobia* nematodes are from *Eucalyptus* spp. from Australia (McLeod *et al.* 1994; Giblin-Davis *et al.* 2001). Eight new species of *Fergusonina* flies, with partial descriptions of another six un-named species (Taylor pers. com. 2001) and seven new species of *Fergusobia*, with partial descriptions of another three un-named species (Davies pers. com. 2001) are currently being described from *Melaleuca*. Little is known of the biology and development of *Fergusonina/Fergusobia* galls on *Melaleuca*.

*Melaleuca quinquenervia* (Cav.) S. T. Blake, the broad-leafed paperbark tree, is widely distributed along coastal streams and in swamps from near Sydney to Cape York in Australia (Holliday 1989) and has become a popular ornamental tree in tropical and sub-tropical regions of the world (Gagné *et al.* 1997). It was introduced into Florida in 1906 (Schmitz *et al.* 1991) and is now regarded as the most problematic weed there (Florida Conservation Foundation 1993). It causes extensive environmental and economic damage (Balciunas & Center 1991) and has invaded more than 200,000 hectares including wetlands (Bodle *et al.* 1994). Conventional control methods, including burning, slashing and application of herbicides have proved ineffective, costly or environmentally unsound (Gagné *et al.*

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1997). In Australia, *M. quinquenervia* is associated with more than 450 herbivorous insects (Balciunas *et al.* 1995a) that suppress its growth (Balciunas & Burrows 1993) and some have potential as biocontrol agents (Balciunas *et al.* 1995a). Various gall-formers found included three species of gall midges (Diptera: Cecidomyiidae) (Gagné *et al.* 1997) and the *Fergusonina/Fergusobia* association (Balciunas *et al.* 1995b). Galls of the *Fergusonina/Fergusobia* act as a "moderately powerful" metabolic sink, and could potentially suppress seed production and reduce tree vigour (Goolsby *et al.* 2000). Hence this association is being considered among a suite of insects as biocontrol agents of *M. quinquenervia* (Balciunas *et al.* 1995b; Goolsby *et al.* 2000).

*Fergusonina/Fergusobia* galls on *Eucalyptus* spp. frequently contain a complex of hymenopteran parasitoid species and herbivorous lepidopteran inquilines, but there have been few studies on these associated insects (Currie 1937; Taylor *et al.* 1996). There is considerable variability between galls in terms of parasitoid populations and species and their emergence (Taylor *et al.* 1996). However, little is known about their effect on *Fergusonina/Fergusobia* galls on *Melaleuca* spp. To assess the potential of *Fergusonina/Fergusobia* spp. as biocontrol agents of *Melaleuca* spp., the role of their parasitoids needs to be examined.

This paper reports on the development of *Fergusonina/Fergusobia* galls on *M. quinquenervia* in southern Queensland and northern NSW and the parasitoids found in them, as determined from field surveys. Both the nematode and the fly are new species, and will be described elsewhere.

## Materials and Methods

Galls were collected from specimens of *M. quinquenervia* in July 1997 from coastal and sub-coastal, seasonally inundated, sites in south-eastern Queensland and north-eastern New South Wales: Peregian National Park (26° 30′ S, 153° 05′ E), Coolum (26° 34′ S, 153° 05′ E), Coolum Airfield (26° 36′ S, 153° 05′ E), Roy's Road (26° 51′ S, 152° 59′ E), Morayfield (27° 07′ S, 152° 58′ E), Burpengary (27° 09′ S, 152° 58′ E), Bracken Ridge (27° 19′ S, 153° 01′ E), Nudgee (27° 23′ S, 153° 06′ E), Chelmer (27° 31′ S, 152° 58′ E), Corinda (27° 32′ S, 152° 58′ E), Pottsville (28° 22′ S, 153° 34′ E), Oxley Park (27° 33′ S, 152° 59′ E), Doolandella (27° 37′ S, 152° 59′ E), and Woodburn (29° 13′ S, 153° 16′ E). Occasional collections were also made from some of these sites in 1996, in December 1997 and July 1998.

Galls that appeared to consist of living tissue and that did not have obvious exit holes were stored in plastic bags at 5° C until examination (within 7 days). Using a scalpel blade, galls were sliced in tap water under a dissecting microscope. Large galls were cut in half and only one part was dissected. Some mature third stage fly larvae and puparia extracted were rinsed and then dissected in 0.8% NaCl for extraction of parasitic nematodes. The morphological characteristics, number of cavities, presence or absence of nematodes, number of fly larvae and/or puparia, number of wasp larvae and/or pupae, and number of lepidopteran inquilines for each gall were recorded. Nematodes were collected and fixed in hot formalin acetic acid (4:1), processed through alcohol/glycerol into pure glycerol by slow evaporation at 40° C, and mounted in glycerol on glass slides for examination (Davies & Lloyd 1996). Pupae and puparia were either preserved in alcohol or kept fresh in plastic vials and checked daily for emergence of insects. Adults emerging from galls were either preserved in 70% alcohol or pinned for identification. Undissected half galls were monitored for emergence of flies, parasitoids and inquilines and any insects emerging were treated as above.

Nematode specimens from this study were deposited in the Waite Institute Nematode Collection (WINC), accession numbers 977 - 981, 984, 985, 994 - 998. Insect voucher material was deposited in the United States Department of Agriculture, Agricultural Research Service, Australian Biological Control Laboratory (ABCL) insect collection.

## Results

### *Description of gall*

Galls (Figs 1, 2) are found throughout the year, though they are more prevalent between April and October. In particular, they occur on the flush of new vegetative growth that occurs mainly during the winter months (Goolsby *et al.* 2000). They usually develop in terminal buds (137 of 177 galls examined from 13 sites in July 1997), either on stems (89.8%) or flower spikes (10.2%), but occasionally develop as axial galls (39 of 177) or at the base of a flower spike (1 of 177). Mature galls were nodular with the appearance of a small bunch of grapes; dissections showed that each nodule contained a cavity. Those on flower spikes were sessile (Fig. 1) but terminal bud galls were stalked (Fig. 2). Some were covered with fine hairs (Fig. 2), others appeared smooth and hairless (Fig. 1).

Galls appear to have arisen from a single bud, with the ventral surface of the leaf/leaves forming the external face of the gall. Some galls, described as "leafy galls" (Fig. 2), had the outer leaves growing as normal leaf tissue beyond the tip. When sectioned, the galled tissue was soft, except around cavities occupied by some hymenopteran inquiline larvae. In

Fig. 1.

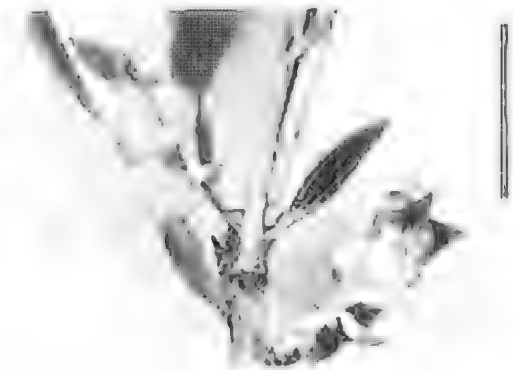

Fig. 2.

Figs 1 - 2. *Fergusonina/Fergusobia* galls on *Melaleuca quinquenervia*. Fig. 1. Mature flower bud gall with exit holes. Scale bar = 1 cm. Fig. 2. Leaf bud galls with leaf material growing beyond the gall. Scale bar = 1 cm.

transverse section, galls were rounded in outline and tissues frequently had a reddish or pinkish tinge. Cavities containing a developing fly larva were oval in longitudinal section and appeared to be surrounded by young, white, undifferentiated plant cells. These cells were absent in cavities containing puparia and around some cavities that contained hymenopteran inquiline larvae. Gall nodules with cavities containing puparia had a window-like area of thin plant epidermis through which the adult fly could emerge.

The average number of nodules per gall collected in 1997 was (mean ± SD) 7.6 ± 5.5 (n = 175, range 1 - 27). In July 1998, fresh weights and lengths and breadths of 33 galls from Chelmer and Corinda were measured, and the number of nodules for each gall was counted. The galls were then sliced up and the number and location of the cavities was noted. Regression analysis showed a linear relationship between the numbers of nodules and the actual number of cavities ($y = 1.8763 + 1.0353x$; $r^2 = 0.716$). The average number of nodules was 10.4 ± 5.6 (range 2 - 24) and cavities 12.6 ± 6.9 (range 3 - 28), i.e. there was an average underestimate of cavities of 18% resulting from galls large enough to contain internal cavities. One small and some larger galls contained some cavities not inside a nodule.

There was a linear relationship between fresh weight and number of cavities per gall ($y = 3.7995 + 70.04x$; $r^2 = 0.584$). Small, soft galls lacking clearly defined nodules averaged 57.2 ± 21.7 mg in weight, 5.0 ± 0.7 mm in length and 4.8 + 0.5 mm in diameter (n = 4), galls with defined nodules but lacking 'windows' averaged 119.0 ± 55.9 mg in weight, 6.3 ± 1.9 mm in length and 5.9 ± 1.6 mm in diameter (n = 12) and galls with both defined nodules and 'windows' averaged 151.0 ± 82.7 mg in weight, 7.5 ± 2.3 mm in length and 7.4 ± 1.4 mm in diameter (n = 18). Small, soft galls contained 8.7 ± 5.1 cavities (range 4 - 16), galls with defined nodules 11.7 ± 7.5 cavities (range 6 – 27) and galls with 'windows' 13.4 ± 6.9 cavities (range 3 - 28).

In December 1997, very small galls (about 3 mm diameter) referred to as 'curled leaf galls' were collected at Morayfield. Leaves growing beyond the galls were uncharacteristically small and distorted. The average number of cavities in these galls was 3 ± 1.9 (range 1 - 8; n = 10).

*Number of insects per gall*

The 175 galls collected from all sites and examined in July 1997 had an average of 6.1 ± 5.2 insects of all types (range 0 – 28) per gall. Seventy galls (40% of the total examined) contained more developing wasps than flies. These galls had an average of 4.0 ± 2.4 wasps per gall (range 1 - 11) and 0.8 ± 1.1 flies per gall (range 0 - 4). Eighty-six galls (49%) contained more flies than wasps, with an average of 6.2 ± 3.6 flies (range 1 - 15) and 0.7 ± 1.1 wasps (range 0 - 6) per gall. However, regression analysis showed that there was a poor relationship between the numbers of wasps and numbers of flies developing in a gall ($r^2 = 0.086$).

Thirty of these galls (17%) contained lepidopteran inquilines, usually associated with webbing and frass. Only one lepidopteran larva, from either of two undetermined species, was present in any one gall. The average number of other insects (developing flies and wasps) per gall containing a lepidopteran larva was 1.4 ± 2.0 (range 0 - 7). In 33% of the galls with lepidopteran inquilines, the larva had eaten out most of the gall and few flies or wasps survived. In one gall, six small fly larvae were found in the remaining shell of plant tissue.

Mites, psyllids and rotifers were found in or associated with galls and thrips occasionally. Other gall inquilines recorded were a coleopteran larva from one gall, and unidentified dipteran larvae from three others.

*Biology of* Fergusobia *associated with* Melaleuca *galls*

Nematodes were found in 54 (30.5%) galls collected from all sites in July 1997, associated with first and second stage and young third stage fly larvae. They were not found in cavities with mature third stage fly larvae, puparia, wasp parasitoids or lepidopteran inquilines. Very few infective female nematodes were collected, and then from only four galls. Examination of infective females from the galls showed that they were inseminated before entering the fly larvae. No parasitic nematodes were found from dissections of male larvae and puparia (n = 18). Female larvae contained an average of 8.3 ± 2.7 parasitic nematodes (range 3 – 11, n = 9) and female puparia 3.9 ± 2.0 (range 0 - 9, n = 15). Unexpectedly, one fly larva contained not only parasitic females but also several male nematodes. Nematode eggs were found in the haemolymph of some puparia, i.e. egg deposition began before the adult fly emerged, and newly emerged female flies contained many juvenile nematodes in the haemolymph.

Galls collected from Morayfield in December 1997 were generally earlier in development than those collected in July and mostly contained only first stage fly larvae. Nematode development was similarly at an early stage, and most of the galls examined contained only parthenogenetic females and juveniles. Of 10 galls dissected, two were parasitised by wasps and contained no nematodes. Of those containing nematodes, only two had males and these were the only galls with second stage fly larvae. The average number of parthenogenetic nematodes per cavity in the galls was 2.2 ± 0.7 (range 1 - 3, n = 8). The average total number of nematodes per cavity was 8.3 ± 5.6 (range 3 - 20).

*Wasp diversity, distribution and status*

In July 1997, eight species of Hymenoptera were reared from pupae dissected from 38 galls from 12 sites (Table 1). Most galls (27) contained wasps of only one species, nine galls contained two species and two galls contained three species. The wasps were *Bracon* sp. (Braconidae), *Eurytoma* sp. (Eurytomidae), *Coelocyba* sp. (Pteromalidae), *Neanastatus* sp. (Eupelmidae), *Cirrospilus* sp. (Eulophidae), *Megastigmus* sp. (Torymidae), and two unidentified species. Of these, *Eurytoma* appeared to be the most widely distributed, being reared from 16 galls at 10 sites. *Coelocyba* (from 11 galls) and *Neanastatus* (from 12 galls) were each reared from six sites, *Bracon* (from 9 galls) from five sites, *Megastigmus* (from 3 galls) from two sites and *Cirrospilus* (from 3 galls) from two sites.

Observations were made of feeding behaviour and/or emergence of particular wasps from isolated puparia. *Coelocyba* sp. emerged from a puparium dissected from a gall, i.e. it is a primary parasitoid of *Fergusonina*. *Eurytoma* sp. emerged from isolated pupae, which had developed from larvae observed feeding ectoparasitically on *Fergusonina* larvae. *Eurytoma* larvae had long, curved mandibles that were protruded for feeding. In two galls, cavities were noted which contained the remains of young second instar flies and which were connected by small 'tunnels' to other cavities containing fly and

TABLE 1. *Hymenopteran spp. reared from pupae isolated from* Fergusonina/Fergusobia *galls collected on* M. quinquenervia *in July 1997.*

| Collection Site | *Bracon* sp. | *Eurytoma* sp. | *Coelocyba* sp. | *Neanastatus* sp. | *Megastigmus* sp. | *Cirrospilus* sp. | Unknown sp. |
|---|---|---|---|---|---|---|---|
| Coolum | | 1 | 1 | | | | |
| Coolum Airfield | | 1 | 1 | | | 1 | |
| Roy's Road | 2 | 2 | | | | | |
| Morayfield | | | | 1 | | | |
| Bracken Ridge | 1 | 1 | 1 | | | | |
| Nudgee | 1 | 3 | 5 | | | | |
| Chelmer | 2 | 3 | 6 | 3 | | | [illegible] |
| Corinda | | | | | 1 | | |
| Pottsville | | 1 | | | 2 | | |
| Oxley Park | | 1 | | 1 | | | |
| Doolandella | | 2 | 1 | 2 | | | |
| Woodburn | 1 | 1 | 1 | 2 | | | |

Figures indicate the number of galls containing the particular insect.

wasp larvae identical to those which developed into *Eurytoma*. Fly larvae attacked by *Eurytoma* had characteristic brown marks on their cuticle, presumably resulting from wounding. Pupae that gave rise to *Bracon* sp. were encased in a loose, soft cocoon surrounded by frass, and were dissected from individual cavities. There was no evidence that they moved from cavity to cavity. Hardening of gall cells, associated with the presence of some hymenopteran inquilines, was observed in four galls.

## Discussion

Given that the length of the *Fergusonina* life cycle, from egg to adult fly, is approximately six weeks (Balciunas *et al.* 1995b) and the flowering period for *M. quinquenervia* is from April to October annually, it seems likely that there are several generations of the fly per year. It remains unclear what happens to the fly over the summer period. It was not possible to determine if the small curled leaf galls collected in December 1997 contained the same species of fly found in the larger nodular galls. If they did, the fly could survive the summer and would not require a diapause.

The work described here has provided the first information on numbers of parthenogenetic female nematodes in young galls on *M. quinquenervia* but the numbers of juvenile nematodes deposited by female flies was not established. This work also has confirmed that infective female nematodes do not enter male flies (Currie 1937) but nothing is known about how they distinguish the sexes. As with *Fergusobia* species on *Eucalyptus* spp. (Fisher & Nickle 1968; Davies unpub.), infective females from *M. quinquenervia* are inseminated while in the gall. The number of female nematodes parasitic in female larvae, puparia and flies from *M. quinquenervia* is higher than for most *Fergusonina* species but the parasitic females were smaller than reported for species on *Eucalyptus* spp (Currie 1937; Fisher & Nickle 1968; Davies unpub.).

Galls on *M. quinquenervia* are much smaller than those found on *E. camaldulensis* Dehnholm (Taylor *et al.* 1996) and contain fewer insects. This supports the suggestion (Taylor *et al.* 1996) that gall size is a reasonable estimate of resource and hence of carrying capacity of the gall.

The biology of gall-associated Hymenoptera is complex and it is often difficult to determine whether a wasp is a primary parasitoid, facultative parasitoid, hyperparasitoid or inquiline (killing the resident insect and then feeding on the gall tissue) (Bouček 1988, Taylor *et al.* 1996). From studies of *Fergusonina/Fergusobia* galls on *E. camaldulensis*, Taylor *et al.* (1996) described *Coelocyba* sp. as most likely to be an inquiline or a primary endoparasitoid. Here, its emergence from a puparium from a gall confirmed its status as a primary parasitoid. *Eurytoma* is a very large genus, containing species with divergent biologies (Taylor *et al.* 1996). Here, *Eurytoma* sp. was observed feeding ectoparasitically on *Fergusonina* larvae. Pupae of *Bracon* sp. were dissected from individual cavities in galls, suggesting that this species of *Bracon* is a solitary ectoparasitoid of *Fergusonina* larvae. The occurrence of *Neanastatus* in these galls was of particular interest, because this seems to be the first record of this genus from *Fergusonina/Fergusobia* galls. Some *Neanastatus* are hyperparasitoids (Schmidt pers. com. 2001). There are several records of it from southern Queensland (Bouček 1988); it is thought to be parasitic in cecidomyiid galls.

Twelve species of Hymenoptera were reared from leaf bud galls on *E. camaldulensis* at Goolwa, South Australia (Taylor *et al.* 1996), six from flower bud galls all on *Eucalyptus* spp. in the Canberra area (Currie 1937) and four from galls on *Syzygium* in India (Harris 1982). Eight genera have been reared here from galls on *M. quinquenervia*, of which five have been previously associated with *Fergusonina*. Fewer species of hymenopteran parasitoids were associated with individual galls on *M. quinquenervia* compared to those on *E. camaldulensis* (Taylor *et al.* 1996). This may be attributable to the smaller size of the galls. In addition, in the Taylor *et al.* study galls were bagged in the field, so that all wasp species emerging were collected. Here, pupae were collected from dissected galls, so that larval stages were generally unidentified, and rare species could have been missed. Of the genera collected from *Melaleuca* galls, *Eurytoma* sp., *Coelocyba* sp. and *Bracon* sp. appear to be most widespread.

Currie (1937) concluded that parasitoids have an important role in the regulation of populations of *Fergusonina* spp. on *Eucalyptus* spp. While this study represents a short time, and gives no information about temporal variation, it confirms that when hymenopteran parasitoids and inquilines are present within galls on *M. quinquenervia*, the number of flies is often reduced. Lepidopteran inquilines often consumed the interior of whole galls, destroying both developing flies and wasps. The efficacy of *Fergusonina* in potential biocontrol programs of *M. quinquenervia* in Florida is therefore likely to be reduced by parasitism, predation and herbivory by local hymenopterans and lepidopterans. However, this may be somewhat compensated for by the oils and terpenes characteristic of *Melaleuca* (Altman 1989) which may act as deterrents to parasitism and herbivory.

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# NEOECHINORHYNCHUS NINGALOOENSIS SP. NOV. (ACANTHOCEPHALA: NEOECHINORHYNCHIDAE) FROM SCARUS GHOBBAN AND S. PSITTACUS (SCARIDAE) FROM WESTERN AUSTRALIA

*BY SYLVIE PICHELIN* & THOMAS H. CRIBB**

**Summary**

Pichelin, S. & Cribb, T. H. (2001) Neoechinorhynchus ningalooensis sp. nov. (Acanthocephala: Neoechinorhynchidae) from Scarus ghobban and S. psittacus (Scaridae) from Western Australia. Trans. R. Soc. S. Aust. (2001) 125(1), 51-55, 31 May, 2001.

Neoechinorhynchus ningalooensis sp. nov. is described from Scarus ghobban Forsskål, 1775 and S. psittacus Forsskål, 1775 (Scaridae) from Ningaloo Reef, Western Australia. The new species is distinguished by having a combination of the following: three circles of six hooks on the proboscis; anterior hooks equal in size (66-68 $\mu$m long), middle hooks (50-58 $\mu$m long), 79% smaller than anterior hooks, posterior hooks (40-44 $\mu$m long) smallest; lemnisci equal in length and extending beyond the proboscis receptacle but not to ovoid testes; terminal papilla absent. This report is the first published account of an acanthocephalan from parrotfish (Scaridae) and the first record of an eoacanthocephalan from the western coast of Australia.

Key Words: Acanthocephala, Neoechinorhynchidae, Neoechinorhynchus, parrotfish, Western Australia, Scaridae, new species.

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KEY WORDS: Acanthocephala, Neoechinorhynchidae, *Neoechinorhynchus*, parrotfish, Western Australia, Scaridae, new species.

## Introduction

*Neoechinorhynchus* (Neoechinorhynchidae: Acanthocephala) has been recorded from about 50 families of fishes world-wide. Three species of *Neoechinorhynchus*, *N. agilis* (Rudolphi, 1819), *N. tylosuri* Yamaguti, 1939 and *N. aldrichettae* Edmonds, 1971 are present in Australian fishes. Another Australian species, *N. magnus* Southwell & Macfie, 1925, was described by Southwell & Macfie (1925) but Edmonds (1982) considered that it might be conspecific with *N. tylosuri*. *Neoechinorhynchus magnus* is currently considered a *species inquirenda* (see Edmonds 1989).

The new species described here was recovered from two species of parrotfishes (Scaridae) from Ningaloo Reef in Western Australia. To our knowledge, no acanthocephalan has previously been recorded from parrotfishes anywhere in the world.

## Materials and Methods

Acanthocephalans were removed from the intestines of *Scarus* spp., washed in tapwater, compressed slightly between two glass slides to evert the proboscis, fixed in 10% Berland's fluid (95% glacial acetic acid and 5% formalin) in tapwater and stored in 70% ethanol. Specimens were examined and measured in temporary glycerol mounts under a coverslip. Drawings were made with the aid of a *camera lucida* and added to by hand. Measurements, presented as the range with the mean in parenthesis, are given in micrometres unless otherwise stated. Width measurements refer to maximum width. Trunk length does not include neck, proboscis or male bursa. In order to compare relative hook sizes of different species, the median of each hook length for each species was determined from the ranges given in the literature.

Abbreviations used: AHC - Australian Helminthological Collection, South Australian Museum, Adelaide; WAM – Western Australian Museum, WA.

### *Neoechinorhynchus ningalooensis* sp. nov. (FIGS 1-3)

*Holotype*: ♂ from intestine of *Scarus ghobban* Forsskål, 1775 (Scaridae), Ningaloo Reef WA, (22° 40′ S, 113° 37′ E), coll: S. Pichelin, T. H. Cribb, D. Capps and K. Hall, April, 2000, WAM V4144.

*Paratypes*: 1♂ and 2♀♀ from intestine of *Scarus ghobban* Forsskål, 1775 (Scaridae), Ningaloo Reef, WA, (22° 40′ S, 113° 37′ E), coll: S. Pichelin, T. H. Cribb, D. Capps and K. Hall, April, 2000, AHC 31406-31408.

*Other material examined*: 1 ♀ from intestine of *Scarus psittacus* Forsskål, 1775 (Scaridae), Ningaloo Reef, WA, (22° 40′ S, 113° 37′ E), coll: S. Pichelin, T. H. Cribb, D. Capps and K. Hall, April, 2000, WAM V4145.

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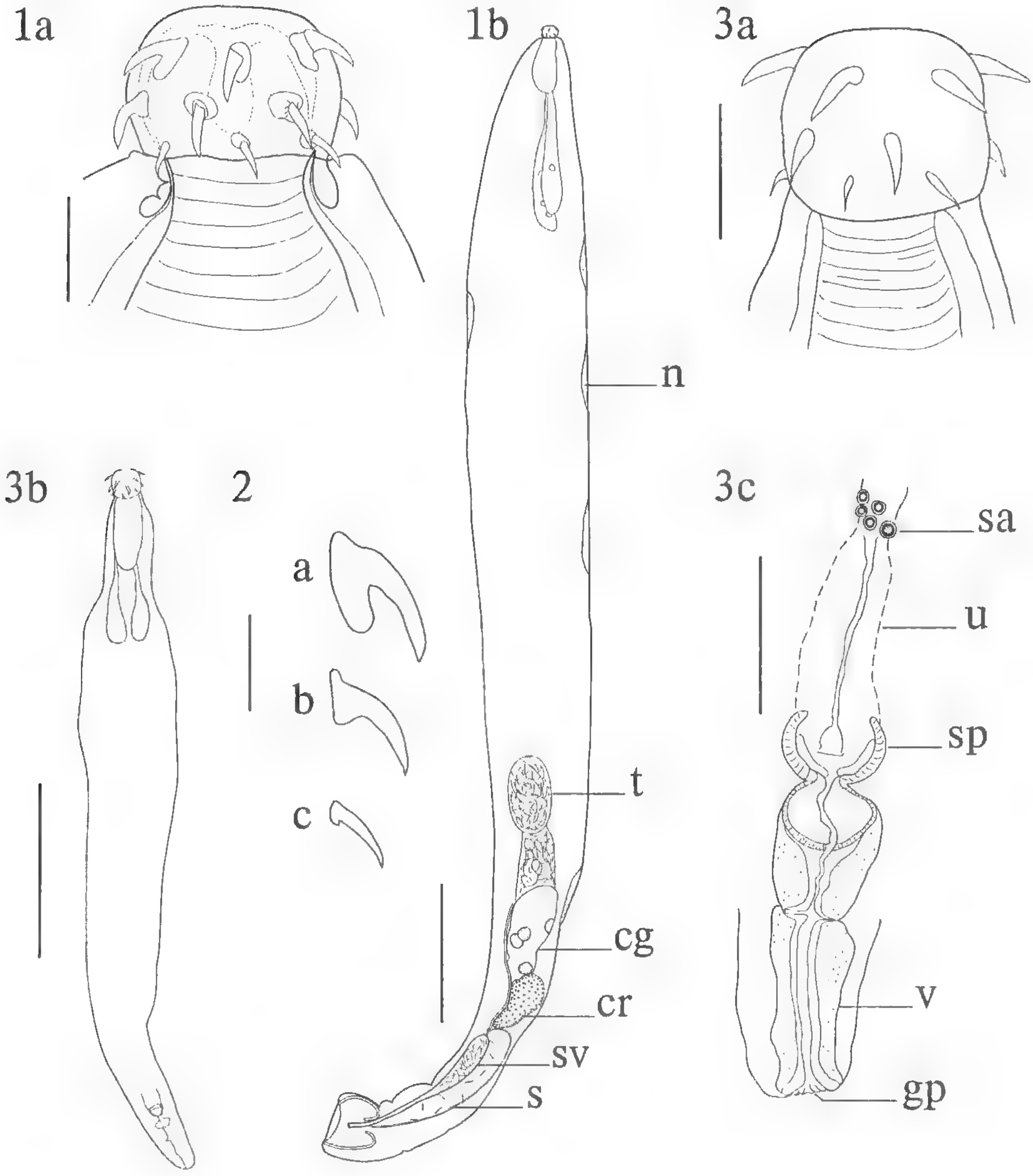


Fig. 1. Male (holotype). a. Proboscis. b. Whole mount. Scale bars = 100 µm, a; 2 mm, b. Legend: cg, cement gland; cr, cement reservoir; n, nucleus; s, Säfftigen's pouch; sv, seminal vesicle; t, testis.

Fig. 2. Proboscis hooks of holotype. a. Hook in anterior circle = anterior hook. b. Hook in middle circle = middle hook. c. Hook in posterior circle = posterior hook. Scale bar = 50 µm.

Fig. 3. Female, immature (paratype). a. Proboscis. b. Whole mount. c. Terminal genitalia – the outline of the uterus (represented by a dashed-line) is estimated by considering the position of the selector apparatus and the vaginal sphincter. Scale bars = 100 µm, a, c; 1 mm, b. Legend: gp, gonopore; sa, selector apparatus; sp, vaginal sphincter; u, uterus; v, vagina.

*Description* (Measurements of specimens from *Scarus ghobban*)

Trunk cylindrical, tapering posteriorly, inerme. Proboscis globular, armed with 3 circles of 6 hooks of similar size in each circle. Hooks in anterior circle robust, slightly curved, equal in size, 66-68 (68); roots robust 41-57 (50) but lacking distinct manubrium. Hooks in middle circle 50-58 (53), approx. 79% smaller than anterior hooks, similar in shape to anterior hooks; roots less developed, stumpier, 27-35 (30). Posterior hooks 40-44 (42), slender, approx. 61% smaller than anterior hooks, approx. 78% smaller than middle hooks; roots ill-defined. Neck inconspicuous or absent. Proboscis receptacle single-walled; brain near posterior end. Hypodermal nuclei present in trunk wall, 5 in holotype. Lemnisci equal in length, single nucleus in one, 3 or more in other; extend beyond proboscis receptacle, about 15% trunk length. Genital pores terminal in both sexes. Terminal papillae absent.

*Males* (n=2 specimens)

Trunk 9.4 -15.8 mm (12.6 mm) x 0.9-1.6 mm (1.3 mm). Proboscis 176-200 (188) x 160-208 (184). Anterior hooks 68-68 (68); roots 41-52 (47). Middle hooks 51-58 (54); roots 27-32 (30). Posterior hooks 40-44 (42). Proboscis receptacle 400-736 (568) x 158-240 (199); 31% of lemnisci length. Lemnisci 1.0 - 2.6 mm (1.8 mm) x 128-272 (198), extend beyond proboscis receptacle but not to testes, occupying 14% of trunk length. Testes 2, ovoid, equatorial, in tandem, contiguous or slightly overlapping; anterior testis 800-1,136 (968) x 400-704 (552); posterior testis 736-1,088 (912) x 480-592 (536). Cement gland multinucleate (4 nuclei observed in holotype). Cement reservoir large, posterior to cement gland. Säfftigen's pouch long, posterior to cement gland, adjacent to seminal vesicle.

*Females* (n= 2 specimens)

Trunk 4 - 8 mm (6 mm) x 0.448 -1 mm (0.8 mm). Proboscis 144-145 (145) x 158-197 (177). Anterior hooks 66-68 (67); roots 57-57 (57). Middle hooks 50-54 (52); roots 28-35 (32). Posterior hooks 40-41 (40). Proboscis receptacle 442-555 (498) x 145-192 (169), 46% of lemnisci length. Lemnisci 656-1,440 (1,072) x 64-176 (120), occupying 18% of trunk length. Uterine bell not visible. Selector apparatus about 116 from vaginal sphincter. Uterus not clearly visible. Vagina thick-walled, 135 long. Gonopore terminal but slightly invaginated. Eggs not observed.

## Remarks

A female specimen of *Neoechinorhynchus ningaloensis* sp. nov. was also recovered from *S. psittacus* in Western Australia. Its measurements are as follows. Trunk 28 x 2.1 mm. Proboscis 189 x 215. Anterior hooks not measurable. Middle hooks 55; roots 27-32. Posterior hooks 41. Proboscis receptacle 976 x 272. Lemnisci 3.2 - 3.4 mm x 304-384.

Five species of scarids were examined from Ningaloo Reef; two of two *S. ghobban* and one of one *S. psittacus* were infected but none of seven *Leptoscarus vaigiensis* (Quoy & Gaimard, 1824), one *Chlorurus sordidus* (Forsskal, 1775) and one *Scarus chameleon* Choat & Randall, 1986 was infected. A further 66 scarids were examined from Heron I., Queensland but no acanthocephalans were found. These species of fish were *Cetoscarus bicolor* (Rüppell, 1829) (n = 1), *Scarus dimidiatus* Bleeker, 1859 (n = 3), *S. frenatus* Lacépède, 1802 (n = 7), *S. ghobban* Forsskal, 1775 (n = 2), *S. globiceps* Valenciennes, 1840 (n = 5), *S. microrhinos* Bleeker, 1854 (n = 1), *S. niger* Forsskål, 1775 (n = 4), *S. oviceps* Valenciennes, 1840 (n = 1), *S. psittacus* Forsskål, 1775 (n = 3), *S. rivulatus* Valenciennes, 1840 (n = 7), *S. schlegeli* (Bleeker, 1861) (n = 4), *S. sordidus* Forsskål, 1775 (n = 27), *S. spinus* (Kner, 1868) (n = 1).

*Etymology*

The specific name of the new species refers to the Australian location in which it was discovered.

## Discussion

Amin (1985a) lists 75 species of *Neoechinorhynchus*. A further 12 have been described since, namely: *N. carinatus* Buckner & Buckner, 1993 (see Buckner & Buckner 1993), *N. dimorphospinus* Amin & Sey, 1996 (see Amin & Sey 1996), *N. gibsoni* Khan & Bilqees, 1989 (see Khan & Bilqees 1989), *N. idahoensis* Amin & Heckmann 1992 (see Amin & Heckmann 1992), *N. lingulatus* Nickol & Ernst, 1987 (see Nickol & Ernst 1987), *N. nickoli* Khan, Bilqees, Noor-Un-Nisa, Ghazi & Ata-Ur-Rahim, 1999 (see Khan, *et al.* 1999), *N. pimelodi* Brasil-Sato & Pavanelli, 1998 (see Brasil-Sato & Pavanelli 1998), *N. plagiognathopitis* Wang & Zhang, 1987 (see Wang & Zhang 1987), *N. roberthaueri* Amin, 1985 (see Amin 1985b), *N. rostratum* Amin & Bullock, 1998 (see Amin & Bullock 1998), *N. saurogobii* Yu & Wu, 1989 (see Yu & Wu 1989) and *N. villoldoi* Vizcaíno, 1992 (see Vizcaíno 1992). Descriptions were examined for all species except *Neoechinorhynchus karachiensis* Bilqees, 1972, *N. quinghaiensis* Liu, Wang & Yang 1981, *N. acanthuri* Farooqi, 1980 and *N. longissimus* Farooqi, 1980. *Neoechinorhynchus karachiensis* and *N. quinghaiensis* are listed by Amin (1985a) but could not be found in the literature. The only reference by Farooqi we could find which contained the descriptions of *N. acanthuri* and *N. longissimus* was in the form of an abstract. If this is the only reference describing *N. acanthuri* and *N. longissimus*, then the species are *nomena nuda* because they have not been formally described.

*Neoechinorhynchus ningalooensis* sp. nov. has been placed in *Neoechinorhynchus* because it has three circles of six hooks on the proboscis, a single-walled proboscis receptacle, a single cement gland and no trunk spines. It can be distinguished from all other species by the combination of the following characters: large hooks of the anterior circle equal in size and measuring 66-68 (68) in length; hooks in the middle circle 50-58 (53), 79% smaller than anterior hooks, posterior hooks smallest, 40-44 (42); lemnisci equal in length and extending beyond the proboscis receptacle but not to the ovoid testes; the trunk without a terminal papilla.

Many *Neoechinorhynchus* species occur only in the Americas in either freshwater fishes or turtles and are therefore unlikely to be confused with *N. ningalooensis* which occurs in an Australian marine fish. There are 15 species, that occur only outside Australia, which have equal sized hooks in the anterior circle on the proboscis and have anterior hooks (55-75 long) similar in length to the new species (66-68). Nine of these also have distinctly unequal lemnisci and/or the middle and posterior hooks about the same size (the posterior hooks are about 90% or more the length of the middle hooks in these species). *Neoechinorhynchus ningalooensis* has lemnisci of equal lengths and the posterior hooks are 78% the length of the middle hooks.

Six species are similar to the new Australian species. These are *N. formosanus* (Harada, 1938) Kaw, 1951, *N. longilemniscus* Yamaguti, 1939, *N. nigeriensis* Farooqi, 1981, *N. rigidus* (Van Cleave, 1928) Kaw, 1951, *N. saginatus* Van Cleave & Bangham, 1949 and *N. salmonis* Ching, 1984 (females only). The middle hooks of *N. formosanus*, *N. longilemniscus*, *N. nigeriensis*, *N. saginatus* and *N. salmonis* are about half the size of the anterior hooks (middle hook 50–57% of anterior hook lengths) whereas the middle hooks of *N. ningalooensis* are about 79% of the length of the anterior hooks. The very long lemnisci which extend almost to the posterior end of the trunk of *N. longilemniscus* also readily distinguish this species from *N. ningalooensis*. *Neoechinorhynchus nigeriensis* is further distinguished from the new species because its posterior hooks are half the size of its middle hooks.

The original description of *N. rigidus* from an Indian fish (*Schizothorax zarundnyi*) by Van Cleave (1928) is brief. Van Cleave (1928) gave the lengths of the anterior, middle and posterior hooks as 70, 47 and 41 μm respectively but very little other information. The similarity between the middle and posterior hook lengths in this species is sufficient to distinguish it from *N. ningalooensis*. Moravec & Amin (1978) described *N. rigidus* from fishes of Afghanistan and gave the length ranges for the anterior, middle and posterior hooks as 60-81, 45-63 and 42-60 respectively. Their figure of the hooks of *N. rigidus* (see Fig. 7 in Moravec & Amin (1978)) also shows the similarity between the middle and posterior hook lengths.

There are only three valid species of *Neoechinorhynchus* in Australia. *Neoechinorhynchus aldrichettae* is known from *Aldrichetta forsteri* (Cuvier & Valenciennes) in South Australia and the other two species *N. tylosuri* and *N. agilis* are known from *Tylosurus* sp. and from *Crenimugil crenilabris* and *Mugil cephalus* (respectively) in Queensland (Edmonds 1989). *Neoechinorhynchus agilis* is also known from *M. cephalus* from Japan and Italy (type locality) (Edmonds 1971). *Neoechinorhynchus tylosuri* is a long slender worm with elongate testes, unequal lemnisci and its middle and posterior hooks are similar in length and about half the size of the anterior hooks (Edmonds 1982) whereas *N. ningalooensis* is more compact, has ovoid testes and its posterior hooks are smaller than its middle hooks. The anterior hooks of *N. agilis* described by Edmonds (1982) may be almost twice the size of those of *N. ningalooensis*. *Neoechinorhynchus aldrichettae* can be distinguished easily from *N. ningalooensis* by the differences in the shape and size of the proboscis hooks and the relative lengths of the lemnisci. The middle and posterior hooks of *N. aldrichettae* are more slender and smaller than its anterior robust hooks whereas the middle hooks of *N. ningalooensis* are more robust and larger than its posterior hooks. The lemnisci of *N. aldrichettae* are about one third as long as the trunk (Edmonds 1982) whereas those of *N. ningalooensis* are about a seventh (15%) of the trunk length.

*Neoechinorhynchus ningalooensis* was recovered from *Scarus ghobban* (type host) and *S. psittacus*. This is the first record of an acanthocephalan infecting species of the family Scaridae. It is also the first record of an eoacanthocephalan from the Indian Ocean off the coast of Western Australia.

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# EMBRYOGENESIS, CULTURE AND DESCRIPTION OF THE FREE-LIVING STAGES OF TWO NEMATODE PARASITES OF THE NORTHERN HAIRY-NOSED WOMBAT (LASIORHINUS KREFFTII) (VOMBATIDAE: MARSUPIALIA)

*By I. R. Smales*, K. Gerhardt* & B. Heinrich**

## Summary

Smales, L. R., Gerhardt, K. & Heinrich, B. (2001) Embryogenesis, culture and description of the free-living stages of two nematode parasites of the northern hairy-nosed wombat (Lasiorhinus krefftii) (Vombatidae: Marsupialia). Trans. R. Soc. S. Aust. 125(1), 57-63, 31 May, 2001.

Faecal pellets were collected from the only extant population of Lasiorhinus krefftii, the northern hairy-nosed wombat, at Epping Forest National Park, Central Queensland. Nematode eggs and larvae, extracted from these pellets, representing 24 h samples from the total host population, were cultured in the laboratory. The eggs, all presumed to be Oesophagostomoides eppingensis hatched as first-stage larvae after 19 –$23^1/_2$ h in distilled water at 25° C. The optimum temperature for larval hatch in faecal culture was 26° C. All larvae had moulted to second-stage by day 3 and to third-stage sheathed larvae by day 5. Third-stage Strongyloides sp. larvae, smaller than larvae of S. spearei occurring in Vombatus ursinus, the common wombat, were also found in the cultures. The developmental strategies of O. eppingensis free-living stages, optimum temperature for hatching and unprotected first and second-stage larvae, are congruent with those of strongylid species native to temperate regions outside Australia but not those of the Australian strongyles Hypodontus macropi, Rugopharynx rosmariae, Labiostrongylus eugenii and Cloacina similis, all of which have protected second-stage larvae and in the case of the latter two species protected first-stage larvae also.

Key Words: Lasiorhinus krefftii, wombat, Oesophagostomoides, eppingensis, Strongyloides sp., nematode life-cycle, free-living stages.

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by L. R. SMALES*, K. GERHARDT* & B. HEINRICH*

## Summary

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KEY WORDS: *Lasiorhinus krefftii*, wombat, *Oesophagostomoides eppingensis*, *Strongyloides* sp., nematode life-cycle, free-living stages.

## Introduction

*Lasiorhinus krefftii* (Owen, 1872) (Vombatidae: Marsupialia) the northern hairy-nosed wombat is now restricted to a single population of about 65 individuals in Epping Forest National Park (EFNP) 120 km north west of Clermont (22° 19′ S, 146° 47′ E), Central Queensland (Crossman *et al.* 1994). Although this species was previously distributed through Queensland, New South Wales and across the border into Victoria, the present reduction in range and numbers is thought to have occurred over the past 120 years (Taylor *et al.* 1994). The northern hairy-nosed wombat is listed as critically endangered (Maxwell *et al.* 1996) and a Recovery Plan is being managed through the Environment Protection Agency of Queensland (Horsup 1999[1]).

The wombats occupy a single burrow system, a series of large burrows arranged in loose clusters along the banks of a sandy gully (Johnson & Crossman 1991). These animals spend 2 - 6 h, only at night, above ground. Burrow entrances are marked with piles of fresh faecal pellets with smaller piles deposited along the paths between the burrows but not elsewhere (Johnson & Crossman 1991). Fresh, that is still moist, pellets collected from the burrow system at dawn can therefore provide a 24 h sample from the total extant population of the wombat.

Two species of gastro-intestinal nematode *Oesophagostomoides eppingensis* Smales, 1994 (Strongylida: Strongylidae) and *Strongyloides* sp. (Rhabditida: Strongyloididae) have been found in the northern hairy-nosed wombat (Smales 1998; Gerhardt *et al.* 2000). Of these two species only one, *O. eppingensis*, produces eggs that pass out with the faeces. Any eggs extracted from wombat faeces collected from EPNS are therefore probably eggs of *O. eppingensis*.

During 1996 and again in 1999 the opportunity arose to collect fresh faecal samples from the wombat population in EFNP. This activity was sanctioned by the Recovery Team. From these samples we were able both to isolate nematode eggs and culture larval nematodes. This enabled us to investigate the embryogensis and hatching of eggs of *O. eppingensis* and to determine the morphology of *O. eppingensis* and *Strongyloides* sp. larvae.

## Materials and Methods

Fresh faecal pellets, collected from EFNP in June and August 1996, and August and September 1999 were transported to Rockhampton on ice and stored at 4° C. Eggs for embryological study were extracted from small amounts of faecal material that had been sedimented with distilled water. Fifteen eggs

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[1] HORSUP, A. (1999) Recovery plan for the northern hairy nosed wombat (*Lasiorhinus krefftii*) 1998 – 2002. Report submitted to Environment Australia by the Northern Hairy-nosed Wombat Recovery Team through the Department of Environment and Heritage Queensland (unpub.)

were measured, placed in hanging drops, held at room temperature (25° C), observed hourly using an Olympus CH3 differential interference microscope, and photographed.

The number of eggs per gram of faeces in the pellets was determined by the standard McMaster technique[2]. Faecal cultures were then established using 1 g faeces, 1 g activated charcoal (8 mm diameter), 5 ml water and 5 drops 4% Nystatin, placed on filter paper in Petri dishes. Preliminary trials were carried out in 1996 and cultures were set up at 18°, 22°, 26° and 28° C for seven days in 1999. The larvae collected were examined live in water or after killing in hot 70% ethanol and clearing in a mixture of 70% ethanol and glycerine and being left until the alcohol had evaporated. Larvae were differentiated into strongyloidid and strongylid forms and the total number of strongylids hatching after seven days, at each temperature, was recorded.

Six strongylid larvae were measured on hatching from the hanging drop preparations described above. First-stage strongylid larvae, collected from a faecal culture one day after its establishment, were transferred into a Petri dish and maintained in a incubator at 28° C for four days. Ten larvae were recovered and measured on establishment of the cultures and a further 10 larvae were removed and measured each day for the next three days.

## Results

By the time the eggs had been transported from EFNP, extracted from faecal pellets and established in hanging drops, embryological development had already commenced, with the embryos having reached about a 16 cell stage. Eggs measured 79 – 92 (88) µm by 42 – 51 (46) µm. The stages of development are shown in Fig. 1 and a time chart of the sequence is given in Table 1.

Elongation of the embryo began at about 9 h, the larviform embryo began actively moving after 10 h, the oesophagus was clearly visible after about 16½ h and the intestine could be differentiated from 18 h. Hatching as first-stage larvae occurred after 19 – 23½ h. Hatching involved the larva twisting actively in a continuous figure-of-eight pattern followed by a pulsating movement against the side of the egg. This pulsating was associated with a bulge in the egg-shell followed by the shell rupturing and the larva emerging as a first-stage larva head or tail first. The hatching process took 2 – 10 min.

Results from the preliminary trials indicated that hatching occurred successfully between 18° and 30° C but not at 4° C. The cumulative numbers of nematodes that had hatched after four days in faecal culture are given, as the percentage hatch, in Fig. 2, and were compared among the four temperature treatments using a Chi squared 2 x 4 contingency table analysis of the proportion of hatched versus unhatched. There was a significant difference among treatments ($\chi^2_3 = 47.49$, $P < 0.001$), so an iterative *a posteriori* analysis was done by progressive removal of the most extreme treatment group. The results of this analysis showed there was no difference in the proportion hatching at 18 or 22° C ($\chi^2_1 = 0.27$, N.S.), but the proportion hatching differed significantly among temperatures of 18, 22 and 28° C (with a smaller proportion hatching at 28° C: $\chi^2_1 = 11.72$, $P < 0.01$) and also among temperatures 18, 22, and 26° C (with a larger proportion hatching at 26° C: $\chi^2_1 = 20.36$, $P < 0.001$). Finally, there was a significant difference between 26 and 28° C in the proportion hatching ($\chi^2_1 = 12.31$, $P < 0.001$). Taken together, these tests differentiated three statistically significant groups. Hatching was lowest at 28° C, intermediate at 18 and 22° C, and higher than both of these groups at 26° C.

Although during collection, transport and storage

TABLE 1. *Time chart of developmental sequence of* Oesophagostomoides eppingensis *eggs kept in hanging drops of distilled water at 25° C.*

| Stage | Time (h) | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 |
|---|---|---|---|---|---|---|---|---|---|
| morula | | | | | | | | | |
| elongation begins | | | | | | | | | |
| vermiform embryo | | | | | | | | | |
| mouth visible | | | | | | | | | |
| oesophagus visible | | | | | | | | | |
| embryo 3 x length of egg | | | | | | | | | |
| intestine well defined | | | | | | | | | |
| hatching | | | | | | | | | |

[2] School of Veterinary Science (1998) Laboratory Manual for Veterinary Parasitology. University of Melbourne (unpub.).

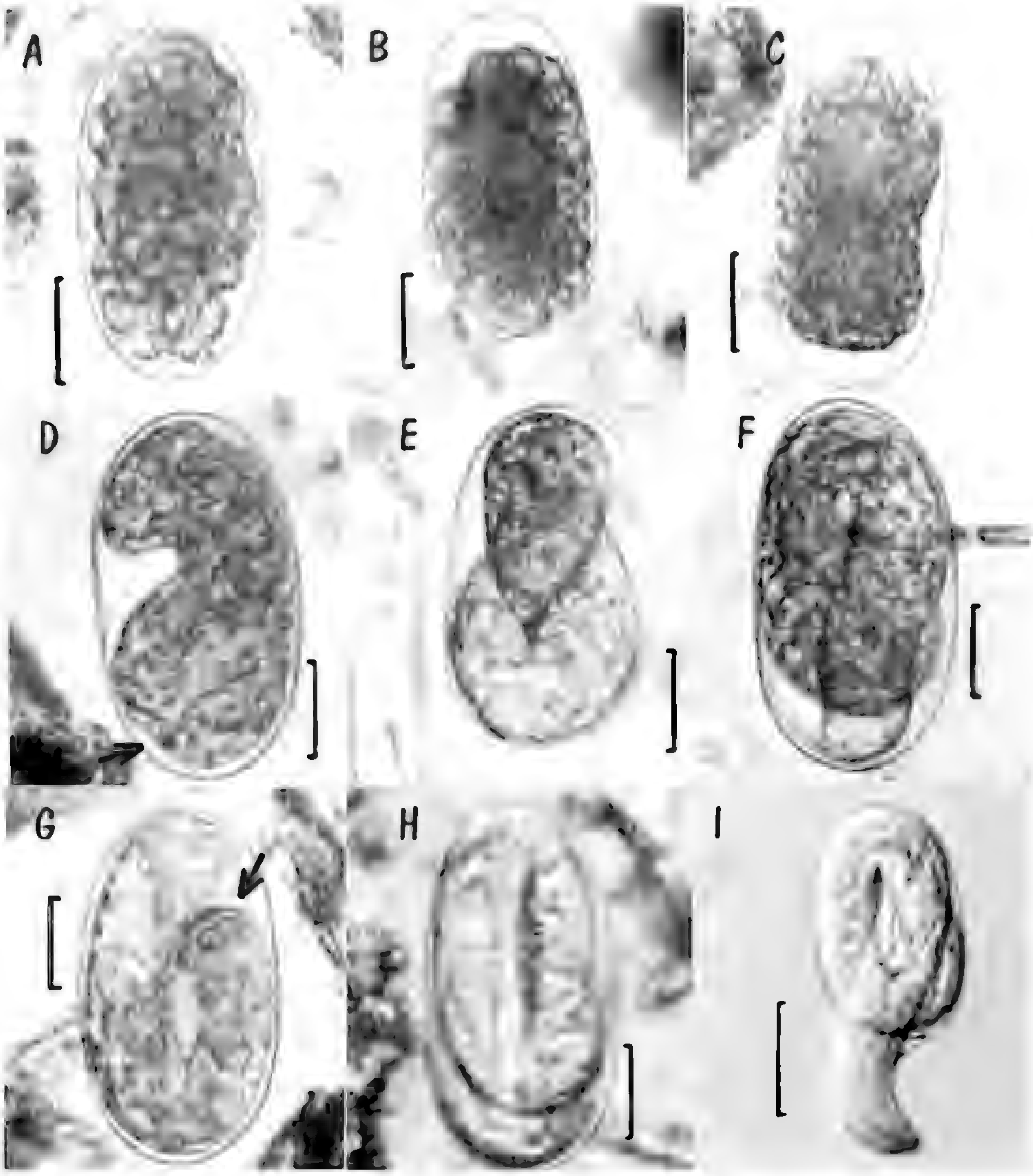



Fig. 1. *Oesophagostomoides eppingensis* eggs kept in hanging drops in distilled water at 25° C. A. After 4 hours. B. After 5 hours. C. After 7 hours, elongation beginning. D. After 9 hours. E. After 11 hours, larviform embryo, elongated to twice the length of the egg, now active. F. After 13 hours, oesophagus forming. G. After 15 hours, larva about three times length of egg. H. After 18 hours, intestine visible. I. After 20 hours, beginning to hatch. Arrows indicate developing mouth. Scale bars = 20 µm.

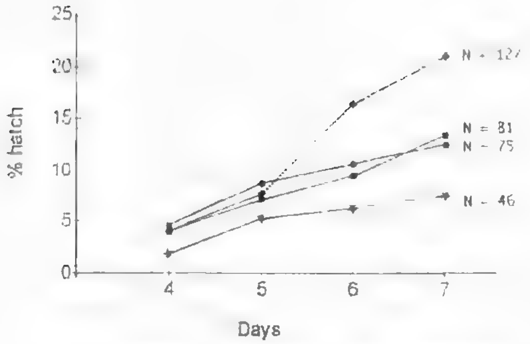



Fig. 2. Percentage of *Oesophagostomoides eppingensis* eggs harvested as larvae from faecal cultures held at a range of temperatures for 7 days —•—•— = 18° C. —■—■— = 22° C. —◆—◆— = 26° C. –✦—✦— = 28° C. N= the number of eggs hatched for each treatment.

faecal pellets were kept moist at about 4° C, the time in storage may have affected the viability of the eggs and hence the overall relatively low hatching rate at all temperatures. Further, the logistics of the exercise precluded both the collection of large amounts of material at any one time and multiple collection events. Notwithstanding these limitations, an informative set of data has been collected.

Measurements of the strongylid larvae are given in Table 2. All larvae had moulted to second-stage by day 3 and to sheathed third-stage by day 5 (Figs 3 & 4). Before moulting the larvae attached themselves to the substrate by the anterior end. Starting from the posterior end, the cuticular sheath became loose and the larva wriggled backwards until it was free, leaving the sheath firmly attached to the substrate. These larval sheaths were detected in the culture on day 3. Although moults to third-stage were not observed, some cuticularisation of the buccal region and greater definition of the lips was apparent by day 5. A small genital anlage could be seen in the third-stage larvae.

Also detected in all faecal cultures on day one was a number of larvae with rhabditiform oesophagus morphology and by day four, forms with a long filariform oesophagus and a notched tail, typical of infective larvae of species of the genus *Strongyloides*, were also apparent. These larvae were 425 – 470 µm long with the oesophagus 200 – 230 µm long, the tail 40 - 58 µm long and the genital anlage 240 – 300 µm from the anterior end (Fig. 5).

## Discussion

The Australian strongylids studied thus far, have free-living larval stages that retain the cuticle of previous moults to sheath subsequent stages. *Rugopharynx rosmariae* Beveridge & Presidente, 1978 and *Hypodontus macropi* Monnig, 1929 both hatch as first stage-larvae and retain the sheaths of the first and second moults, so that the second-stage larva is sheathed and the third-stage larva has a double sheath (Beveridge & Presidente 1978; Beveridge 1979). *Labiostrongylus eugenii* Johnston & Mawson, 1940 hatches as a second-stage sheathed larva and moults to a third-stage double sheathed larva (Smales 1977) and *Cloacina similis* Johnston & Mawson, 1939 hatches as a third-stage double-sheathed larva (Clark 1971[1]).

By contrast *O. eppingensis* hatches as a first-stage unsheathed larva and retains only the second-stage cuticle as a single sheath around the third-stage larva. These differences in stage of hatching are reflected in the time taken from the beginning of embryogenesis to hatching, 19 – 23 h for *O. eppingensis*, 12 h for *H. macropi*, 20 – 40 h for *R. rosmariae* and 67 – 114 h for *L. eugenii* (Smales 1977; Beveridge & Presidente 1978; Beveridge 1979). The time *O. eppingensis* took to hatch and then develop to third-stage sheathed larva (4 days at 28° C) is consistent with the life cycle patterns given by Anderson

TABLE 2. *Measurements (µm) of* Oesophagostomoides eppingensis *in distilled water culture at 25° C.* Ten larvae were removed and measured each day. The range is followed by the mean.

| Day | Larval Stage | Length | Width | Oesophagus length |
|---|---|---|---|---|
| 0 | 1 | 277 – 323 (292) | 22 – 27 (24) | 58 – 77 (69) |
| 1 | 1 | 325 – 365 (344) | 19 – 25 (22) | 73 – 83 (78) |
| 2 | 1 | 355 – 383 (369) | 21 – 27 (24) | 88 – 98 (93) |
| 3 | 2 | 384 – 416 (400) | 22 – 28 (25) | 93 – 103 (98) |
| 4 | 2 | 438 – 462 (450) | 26 – 30 (28) | 95 – 111 (103) |
| 5 | 3 | 490 – 545 (528) | 28 – 41 (34) | 119 – 132 (128) |

[1] CLARK, H. (1971) A preliminary investigation into the free-living stages of two nematode parasites of the Kangaroo Island Wallaby (*Macropus eugenii*) BSc (Hons) Thesis, The University of Adelaide (unpub.)

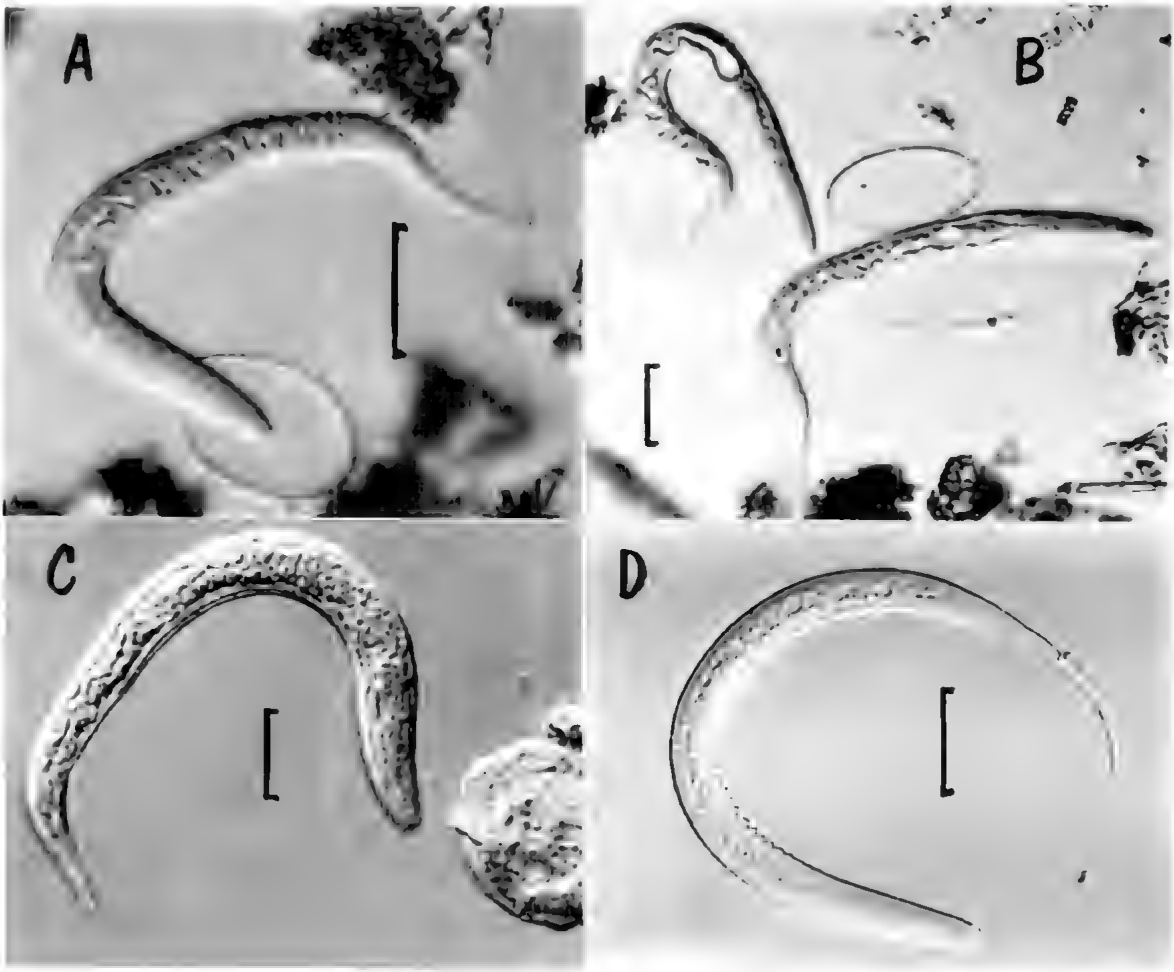
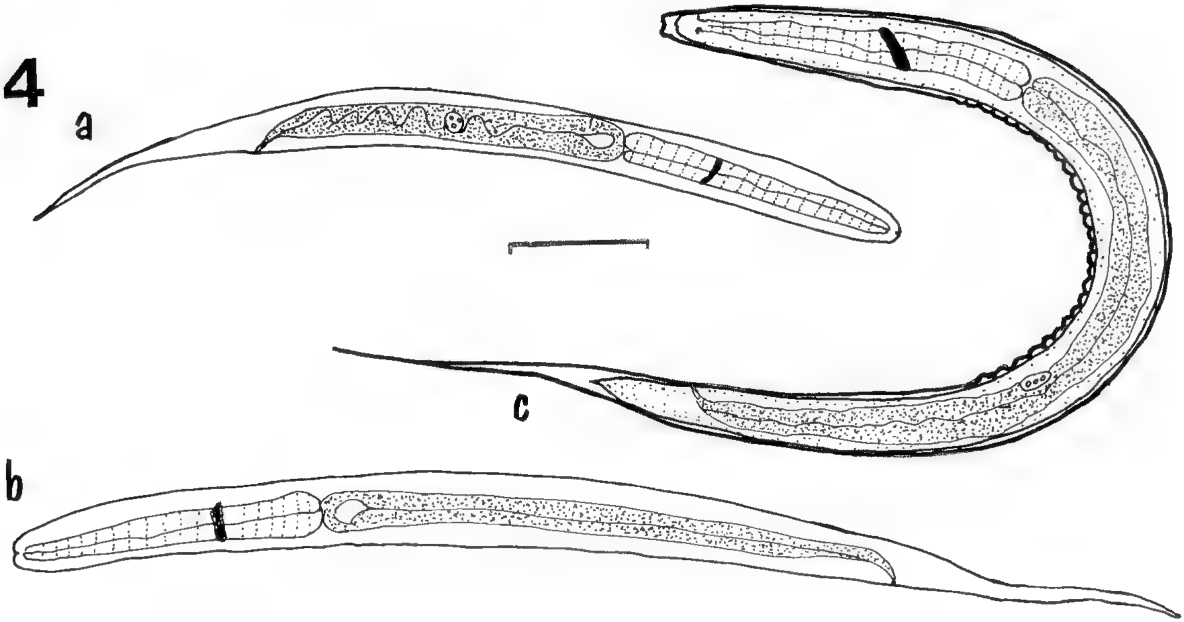



Fig. 3. *Oesophagostomoides eppingensis* larval development when cultured in distilled water at 25° C for 4 days. A. Hatching. B. First-stage larva, day 1. C. Second-stage larva, day 3. D. Third-stage larva, day 4. Scale bars = 40 µm A – C; 70 µm D.

(2000) for the superfamily Strongyloidea, to which *Oesophagostomoides* belongs.

The process of hatching, including increased larval movement, for *O. eppingensis* follows the basic pattern suggested by Bird & Bird (1991) as common to all nematodes. The escape of the larva by mechanical disruption of part of the egg shell is similar to that described for *L. eugenii* (Smales 1977) and could therefore also involve enzyme action to effect a change in permeability of the egg and increase plasticity of the shell (Smales 1977).

Examination of eggs and larvae confirmed previous suggestions (Smales 1994; Gerhardt *et al.* 2000) that only two species of intestinal nematode occur in *L. krefftii*. Measurements of eggs in this study (88 – 92 µm x 42 – 50 µm) are consistent with measurements of eggs of *O. eppingensis* and fall within the size range of eggs of other intestinal nematodes occurring in wombats (Beveridge 1978). The range of temperatures at which egg hatching occurred, 18 – 30° C is consistent with that recorded for other strongylids. For example, the eggs of *Chabertia ovina* (Fabricius, 1788) hatch between 6 and 36° C, *Strongylus vulgaris* (Looss, 1900) between 8 and 39° C, *Oesophagostomum columbianum* Curtice, 1890 between 15 and 37° C and *Castorstrongylus castoris* Chopin, 1925 between 18 and 25° C (Anderson 2000). Given the hot, dry climate of EFNP, we expected that the optimum temperature for hatching would have been at the high end of the range such as, for example, 30° C recorded for *S. vulgaris* and *O. columbianum* (Anderson 2000). The optimum was, however, 26° C, a temperature reported as optimum for *C. ovina* and close to the 25° C optimum reported for a number of strongylids, such as *Ostertagia ostertagi* (Stiles, 1892), *Trichostrongylus axei*



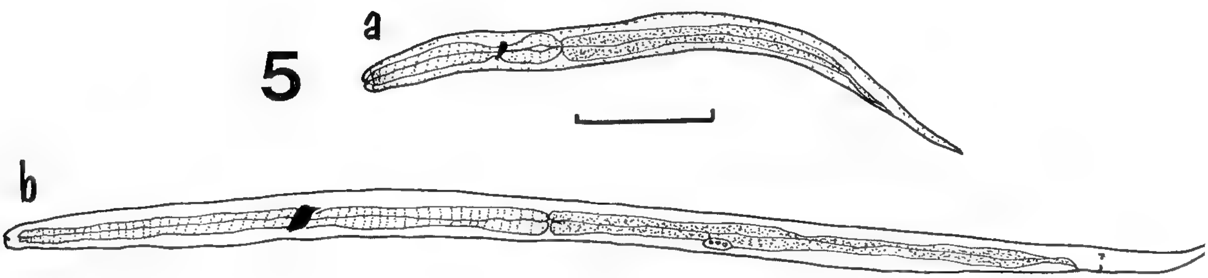




Fig. 4. *Oesophagostomoides eppingensis* free-living stages. a. First-stage larva. b. Second-stage larva. c. Third-stage infective larva. Scale bar = 50 µm.

Fig. 5. *Strongyloides* sp. Free living stages. a. Rhabditiform first or second-stage larva. b. Filariform third-stage infective larva. Scale bar = 50 µm.

(Cobbold 1879), *Syngamous trachea* (Montagu, 1811) and *Ancylostoma caninum* (Ercolani, 1859), found in temperate climates (see Anderson 2000). One possible explanation is that eggs might go into a state of arrested development at high temperatures, as has been reported for the eggs of animal parasitic and plant parasitic nematodes (Waller & Donald 1972; Bird & Bird 1991), to ensure survival.

Of the three morphotypes of larvae found in faecal cultures, the first morphotype was a typical strongylid. No obvious differences in size, growth rate or morphology of this type were detected during culture, lending weight to the presumption that these larvae represented a single species, namely *O. eppingensis.*

The other two morphotypes could clearly be designated developmental larval stages of species typical of the family Strongyloididae. Although both genera *Parastrongyloides* and *Strongyloides* occur in marsupials, only a *Strongyloides* species has been reported from vombatids (Skerrat 1995). Consequently these larvae are presumed to be *Strongyloides* sp., possibly *S. spearei* Skerrat, 1995, occurring in the common wombat (see Skerrat 1995). The infective larvae we found, however, were smaller (mean lengths of 445 µm compared with 529 µm) with a shorter oesophagus (210 µm compared with 236 µm) a shorter tail (47 µm compared with 79 µm) and with the genital anlage closer to the anterior end (277 µm compared with 324 µm) than in *S. spearei*. They may, therefore, be either a distinct species or represent a population of smaller worms than populations of *S. spearei* from the common wombat. A more detailed examination of all stages of the life cycle, particularly by culturing larvae through to adults, is needed before the specific status of the *Strongyloides* sp. from the northern hairy-nosed wombat can be determined.

The hatching of *L. eugenii* as a sheathed second-stage larva was thought by Smales (1977) to be a protective response to the potential for desiccation of eggs and larvae under Australian climatic conditions. Neither this strategy nor a preference for higher temperatures for hatching success has evolved in *O. eppingensis*. Monitoring for the presence of intestinal helminths in the EFNP population through 1996 (Gerhardt *et al.* 2000) has shown that *O. eppingensis* is present throughout the year. Larvae must, nevertheless, be sufficiently robust to survive the hot summers and dry winters typical of Central Queensland. Further work is needed to determine the level of heat tolerance and responses to desiccation of *O. eppingensis* and how they relate to the life-cycle strategies of the parasite. A better understanding of the dynamics of the free-living stages could be useful when developing management strategies for the wombat host population.

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# A DISJUNCT POPULATION OF EUCALYPTUS GLOBULUS SSP. BICOSTATA FROM SOUTH AUSTRALIA

*By R. E. Vaillancourt*, D. B. Boomsma† & D. Nicolle‡*

## Summary

Vaillancourt, R. E., Boomsma, D. B. & Nicolle, D. (2001) A disjunct population of Eucalyptus globulus ssp. bicostata from South Australia. Trans. R. Soc. S. Aust. 125(1), 65-68, 31 May, 2001.

A population of Eucalyptus globulus ssp. bicostata was recently discovered at Mt. Bryan (SA) which is more than 600 km from the nearest other population of this taxon. The aim of this study was to determine whether this population is natural or whether it might have been planted after the arrival of pastoralists to the area. To achieve this aim we used RAPD molecular marker analysis of a large (10 m diam) lignotuberous stand of E. globulus ssp. bicostata that roughly formed a ring. The RAPD analysis indicated no differences between samples taken from the lignotuberous stand, although individuals from outside it were all different from it and from one another. Because the lignotuberous stand of E. globulus ssp. bicostata is likely to originate from a single individual and is very large, it is likely to be very old (possibly as old as 4,000 years) and this would imply that the population was not established by pastoralists. How did the E. globulus spp. bicostata become established on Mt. Bryan? Four possibilities are discussed, namely, natural long distance seed dispersal, seed dispersal by humans before the arrival of pastoralists, long distance pollen dispersal and connection to the Victorian Eucalyptus globulus ssp. bicostata forest in the past.

Key Words: Lignotuber, clone size, RAPD, fingerprinting.

*Transactions of the Royal Society of S. Aust.* (2001), **125**(1), 65-68.

# A DISJUNCT POPULATION OF *EUCALYPTUS GLOBULUS* SSP. *BICOSTATA* FROM SOUTH AUSTRALIA

by R. E. VAILLANCOURT*, D. B. BOOMSMA† & D. NICOLLE‡

## Summary

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A population of *Eucalyptus globulus* ssp. *bicostata* was recently discovered at Mt Bryan (SA) which is more than 600 km from the nearest other population of this taxon. The aim of this study was to determine whether this population is natural or whether it might have been planted after the arrival of pastoralists to the area. To achieve this aim we used RAPD molecular marker analysis of a large (10 m diam) lignotuberous stand of *E. globulus* ssp. *bicostata* that roughly formed a ring. The RAPD analysis indicated no differences between samples taken from the lignotuberous stand, although individuals from outside it were all different from it and from one another. Because the lignotuberous stand of *E. globulus* ssp. *bicostata* is likely to originate from a single individual and is very large, it is likely to be very old (possibly as old as 4000 years) and this would imply that the population was not established by pastoralists. How did the *E. globulus* ssp. *bicostata* become established on Mt Bryan? Four possibilities are discussed, namely: natural long distance seed dispersal, seed dispersal by humans before the arrival of pastoralists, long distance pollen dispersal and connection to the Victorian *Eucalyptus globulus* ssp. *bicostata* forest in the past.

KEY WORDS: Lignotuber, clone size, RAPD, fingerprinting.

## Introduction

A population of *Eucalyptus globulus* ssp. *bicostata* (Maiden, Blakely & J. Simm.) Kirkpatr. was recently discovered at Mt Bryan SA (33° 26′ S, 138° 57′ E) by B. Bates. This population is unusual in that it is more than 600 km from the nearest known *E. globulus* ssp. *bicostata* population (Otway Ranges, Victoria) and is the only population of that species west of the Murray-Darling drainage system. The population is situated on the slopes of a high ridge south-west of the summit of Mt Bryan, at an altitude between 680 and 890 m. The entire population consists of approximately 80 apparently very old, large individuals and between 160 and 180 "sapling stage" individuals with a stem diameter of less than 300 mm just above ground level. Small seedlings at the cotyledon to the fifth leaf-pair stage were observed at the site in 1996/97 but seedlings were not observed in August 2000. They may have been removed by sheep. The population has a range of approximately 1000 m and forms three sub-populations separated by c. 200 m each, the western sub-population being the largest. Sapling stage individuals were more plentiful in, although not restricted to, the relatively lower elevations within the population. The *E. globulus* ssp. *bicostata* trees ranged in height from less than 5 to 18 m. The understorey was dominated by native grasses and herbs, although some *Allocasuarina verticillata* (Lam.) L. Johnson and *Bursaria spinosa* Cav. occurred within the population. Six plant species occurring at the site are classified as rare or endangered, namely, *Asplenium flabellifolium* Cav., *Derwentia decorosa* (F. Muell.) B. G. Briggs & Ehrend., *Hymenanthera dentata* R. Br. ex DC., *Lepidium pseudo-tasmanicum* Thell., *Olearia pannosa* Hook. ssp. *pannosa*, and *Rhodanthe anthemoides* (Sprengel) Paul G. Wilson (P. J. Lang, pers. comm. 2000). No other eucalypts occurred with *Eucalyptus globulus* ssp. *bicostata*. Further down Mt Bryan the ssp. *bicostata* population is grassland down to midway on the south-western slope. Below this grassland is open *E. leucoxylon* F. Muell. /*E. porosa* F. Muell. ex Miq. /*A. verticillata* woodland. The local area is one of the coldest in South Australia, with the nearest temperature-recording weather station at Yongala recording average winter minima of 2.5° C and an extreme (July) minimum of minus 8.2° C, the lowest in SA (Bureau of Meteorology; http://www.BoM.GOV.AU/climate/).

In eucalypts, vegetative propagation occurs through lignotubers. A lignotuber is a semi-subterranean woody mass of stem-like tissue that gives protection to a large reserve of epicormic buds. These allow rapid regeneration after stem destruction or damage by fire or other causes (Jacobs 1955;

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Chattaway 1958). Lignotubers occur in the majority of *Eucalyptus* (L'Hérit.) species at some stage in their life cycle (Jacobs 1955). Repeated damage to a tree can result in extensive lignotuber development and formation of a multi-stemmed stand (Lacey & Johnston 1990). Eucalypts capable of vegetative regrowth can live longer than single-stemmed trees (Tyson *et al.* 1998).

The question has been raised as to whether this South Australian population of *E. globulus* ssp. *bicostata* is natural or whether it might have been planted after the arrival of pastoralists to the area. A large stand of *E. globulus* ssp. *bicostata* that roughly formed a ring shape was found at the site at about 850 m altitude in the western sub-population. This stand is very large, being 10 m in diameter and potentially could have arisen from lignotuberous growth. Other lignotuberous stands of a similar size and possibly even larger are also present at the site, but are more difficult to identify because of lignotuber fragmentation and non-circular development of the stand.

Molecular markers are essential in identifying individual genotypes and studying vegetative propagation because the clonal nature of some vegetation cannot be established with confidence by morphological assessment alone. Random Amplified Polymorphic DNA (RAPD) (Williams *et al.* 1990; Welsh & McClelland 1990) is a useful type of molecular marker for the study of genetic variation since numerous loci can be sampled. RAPD analysis has been used extensively in eucalypts, in detecting differences between closely related species and hybrids (Sale *et al.* 1996; Rossetto *et al.* 1997), in studies of genetic diversity and population structure (Nesbitt *et al.* 1995; Skabo *et al.* 1998), in fingerprinting studies (Keil & Griffin 1994; Nesbitt *et al.* 1997; Vaillancourt & Skabo 1999), in studies of breeding systems (Gaiotto *et al.* 1997) and in studies of vegetative propagation by lignotuber (Kennington *et al.* 1996; Tyson *et al.* 1998; Rossetto *et al.* 1999). The aim of this study was to determine whether the large lignotuberous *E. globulus* ssp. *bicostata* stand is clonal. If it is, then its large size would imply that it is very old suggesting that the population could not have been established by pastoralists.

## Materials and Methods

Mature adult leaf material from eight *Eucalyptus globulus* ssp. *bicostata* samples was weighed and frozen in liquid nitrogen prior to use. Four of these samples were from the possible clone and four other samples came from trees away from the lignotuberous stand. The four samples from the possible clone came from the four cardinal points of the lignotuber. Total genomic DNA was isolated from 2.0 g of leaf material according to the CTAB method of Doyle & Doyle (1990).

The DNA from each tree was assayed for Random Amplified Polymorphic DNA (RAPD) markers (Welsh & McClelland 1990; Williams *et al.* 1990). Amplification conditions were as in Nesbitt *et al.* (1997). Primers were obtained from Operon Technologies Inc. (10000 Atlantic Ave., Alameda CA 94501 USA) and the University of British Columbia (6174 University Boulevard, Vancouver, B.C. V6T 1Z3). Twenty-four primers previously shown to produce polymorphic bands (Vaillancourt & Skabo 1999) were used: OPA-02, OPA-14, OPA-15, OPA-17, OPA-20, OPB-05, OPC-19, OPD-05, OPE-07, OPF-04, UBC 30, UBC 210, UBC 215, UBC 217, UBC 218, UBC 232, UBC 234, UBC 237, UBC 243, UBC 249, UBC 266 and UBC 290. Amplified fragments were electrophoretically separated in a 1.5% w/v agarose gel, using 1 X TBE buffer, and photographed after staining with ethidium bromide. Consistency of interpretation was established by repeating three samples with each primer. In general bands were not scored if they were faint or diffuse, or occurred in the extremes of the amplified size range. Only bands that were present in 25% to 75% of the samples were used in the analysis, as reported in Skabo *et al.* 1998.

The presence/absence of RAPD bands was used to calculate a similarity matrix of simple matching coefficients (Sokal & Sneath 1963), using the NTSYS program (Rohlf 1993). The simple matching coefficient (SM) is defined as the total number of matches (shared absence or presence) between two individuals, divided by the total number of bands scored. The same program was then used to calculate the clustering of trees with the UPGMA algorithm and a dendrogram showing the relatedness of the samples was produced.

## Results and Discussion

Forty eight polymorphic bands that met our selection criteria were scored for the eight DNA samples. Samples 1-4 from the possible lignotuberous stand were identical with a similarity of 1.0 (Table 1). Samples 5-8 were all different from one another and from samples of the lignotuberous stand (Fig. 1). The tree most closely related to the lignotuberous stand, tree 5, joined the lignotuberous stand samples at a level (SM = 0.58) that shows that it is not closely related to it. Nesbitt *et al.* (1997) found that RAPD variation within clones was trivial compared to the variation found even between full-siblings and that similarity decreased with pedigree distance. The lack of any variation between samples from the lignotuberous stand and the much lower degree of similarity with the rest of the samples, over

TABLE 1. *Simple matching coefficient (SM) measure of similarity between samples from a* Eucalyptus globulus *ssp.* bicostata *population at Mt Bryan in South Australia calculated with RAPD markers*

| | Sample number (no.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 1.00 | | | | | | | |
| 2 | 1.00 | 1.00 | | | | | | |
| 3 | 1.00 | 1.00 | 1.00 | | | | | |
| 4 | 1.00 | 1.00 | 1.00 | 1.00 | | | | |
| 5 | 0.61 | 0.59 | 0.57 | 0.57 | 1.00 | | | |
| 6 | 0.34 | 0.35 | 0.34 | 0.34 | 0.17 | 1.00 | | |
| 7 | 0.43 | 0.43 | 0.43 | 0.43 | 0.40 | 0.40 | 1.00 | |
| 8 | 0.32 | 0.33 | 0.34 | 0.34 | 0.38 | 0.49 | 0.66 | 1.00 |

Samples 1-4 are from the 10m wide lignotuberous stand, while samples 5-8 are from individual trees in the vicinity of the stand

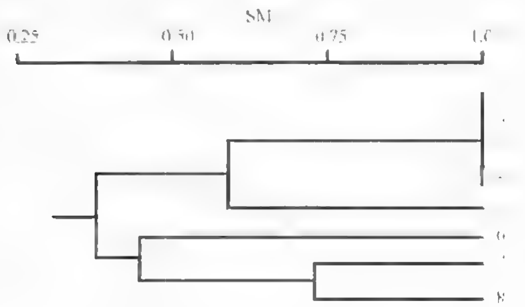


Fig. 1. UPGMA clustering of samples from a *Eucalyptus globulus* ssp. *bicostata* population at Mt Bryan in South Australia based on a simple matching coefficient (SM) measure of similarity calculated with RAPD markers. Samples 1-4 are from the 10m wide lignotuberous stand, while samples 5-8 are from individual trees in the vicinity of the stand.

a relatively large number of polymorphic bands, is very strong evidence for the clonality of samples 1-4. Assuming the growth rate of the *E. globulus* ssp. *bicostata* lignotuber was similar to that given by Tyson *et al.* (1998) for *E. risdonii* Hook. F. and *E. amygdalina* Labill. of about 2.5 mm/year, then it would have taken 4000 years for the *E. globulus* ssp. *bicostata* lignotuber to achieve its present size. This growth rate was comparable to that observed in *E. oleosa* F. Muell. ex Miq by Wellington *et al.* (1979), but greater than that obtained for a two metre diameter lignotuber of *E. coccifera* J. D. Hook (Head & Lacey 1988). We cannot say how old this individual really is, but it is probably much more than 200 years old. This population of *E. globulus* ssp. *bicostata* is therefore most likely to be natural and indeed an interesting remnant that deserves conservation. Although the site is being grazed by sheep (which would affect the rare understorey species and the eucalypt regeneration), the trees are long lived and not noticeably affected by grazing. Thus the population is not under any short term risk from the current land practices.

How did the *E. globulus* ssp. *bicostata* get established on Mt Bryan? One possibility is that it moved to this site through natural long distance seed dispersal. However, this eucalypt taxon, like most eucalypts, lacks adaptation for long distance seed dispersal (Potts & Wiltshire 1997). A related possibility is that this population was established from seed transported by aborigines. Another possibility is that it could have moved as ssp. *bicostata* pollen coming from afar and hybridising with an unknown resident eucalypt species, such as the related *E. goniocalyx* F. Muell. ex Miq. which occurs within 60 km of the site (see Potts & Reid 1988 for an example of this evolutionary mechanism). This would explain why the chloroplast DNA of this population is of a type very different from that encountered in other populations of *E. globulus* so far surveyed (Jackson *et al.* 1999). None of these hypotheses can be disproved. However, perhaps the simplest explanation for the occurrence of *E. globulus* ssp. *bicostata* at Mt Bryan is that the Victorian *E. globulus* ssp. *bicostata* populations were once connected to Mt Bryan at some time in the past. When this would have occurred is a matter for speculation. It is unlikely to have been in the last 35,000 years since the current aridity and the even greater aridity around the glacial maximum make it unlikely that the Murray Basin could have sustained *E. globulus* ssp. *bicostata* populations. It has often been assumed that this aridity may have been fairly constant from the Eocene to mid Miocene marine incursion into the Murray Basin (Marginson & Ladiges 1988). However, recent evidence from Lake Eyre suggests that there might have been wetter periods between 50,000 and 35,000 years BP (Magee & Miller 1998). Therefore, it is possible that during these or other previous wetter periods, an *E. globulus* ssp. *bicostata* forest could have been more or less continuous from Victoria to Mt Bryan in South Australia.

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# PISONIA GRANDIS DOES NOT APPEAR TO HARBOUR FUNGI KNOWN TO INVADE SEA TURTLE NESTS AT HERON ISLAND, EASTERN AUSTRALIA

*Brief Communication*


**Summary**

Hatching success of loggerhead sea turtle nests is significantly lower at Heron I. (23˚26´ S, 151˚55´ E-Capricorn Group, southern Great Barrier Reef), than on the adjacent mainland[1]. Fungal invasion appears to play a major role in inter-specific and inter-habitat variation in egg mortality between loggerhead (Caretta caretta L.) and green (Chelonia mydas L.) sea turtles at coral cay and mainland rookeries[1], and hawksbill (Eretmochelys imbricata L.) and flatback (Natator depressus Garman) turtles at other major rookeries in eastern Australia*.

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BRIEF COMMUNICATION

# *PISONIA GRANDIS* DOES NOT APPEAR TO HARBOUR FUNGI KNOWN TO INVADE SEA TURTLE NESTS AT HERON ISLAND, EASTERN AUSTRALIA

Hatching success of loggerhead sea turtle nests is significantly lower at Heron I. (23°26′ S, 151°55′ E, Capricorn Group, southern Great Barrier Reef), than on the adjacent mainland[1]. Fungal invasion appears to play a major role in inter-specific and inter-habitat variation in egg mortality between loggerhead (*Caretta caretta* L.) and green (*Chelonia mydas* L.) sea turtles at coral cay and mainland rookeries[2], and hawksbill (*Eretmochelys imbricata* L.) and flatback (*Natator depressus* Garman) turtles at other major rookeries in eastern Australia*.

The fungi *Fusarium oxysporum* Schlecht., *F. solani* (Mart.) Sacc. and *Pseudallescheria boydii* Negroni and Fischer have been isolated from failed turtle eggs at Heron I.[2] *Pseudallescheria boydii* is an opportunistic infectant of humans and other animals[3] but there is no record of its being involved in plant disease. However, numerous strains of *F. oxysporum* are wilt pathogens and *F. solani* may cause root rot, canker and wilts[4]. Since one of the most distinguishing features of Heron I. is the dense, central *Pisonia grandis* R. Br. forest, it seems possible that this might be acting as a reservoir for anthracnose fusaria which are also able to invade sea turtle nests.

In its wild state *P. grandis* (Nyctaginaceae) is almost exclusively confined to small uninhabited islands with large seabird colonies[5,6], throughout the Indian and Pacific Oceans[5,6,7,8,9]. In the Capricorn/Bunker group of the southern Great Barrier Reef, *P. grandis* is found on all of the islands. A central forest is usually surrounded by natural fringing vegetation, although erosion may bring the forest to the beachfront[7]. The presence of such forests appears heavily reliant upon abundant seabirds and a specific soil and rock base[6,9]. The Jemo Series[10] are richly organic, acidic, phosphatic, soils in association with a hardpan or coral conglomerate transformed into calcium phosphate[11]. This edaphic condition occurs only on coral and coral debris beneath bird colonies[5] and is almost exclusive to forests dominated by *P. grandis*[11].

*Pisonia grandis* is often associated with islands hosting pigeons, gannets (*Sula* spp.) or noddy terns (*Anous* spp.). If the bird colonies desert the islands, for whatever reason, the *P. grandis* forest disappears as it seems unable to survive without the phosphate enriched soil[6,7] that aids germination and early development[6]. It is believed *P. grandis* utilises seabirds for epizoic dispersal[9], although this has been disputed[12].

Previously, the only fungus associated with *P. grandis* at Heron I. was an unidentified basidiomycete ectomycorrhizal symbiont[13]. This fungus appears to be unique to *P. grandis* or at least have a limited host range[14], and could not be one of the three turtle nest mycoflora reported[2] as none of these is a basidiomycete.

To determine whether *P. grandis* harboured any of the fungal species isolated from failed eggs in sea turtle nests, five individual *P. grandis* trees at the Heron Island Research Station, whose foliage showed anthracnoses, were examined. Two leaves from each tree were collected and washed with sterile, distilled water to remove bird guano before refrigerated storage. Leaf fragments (1cm²) were surface sterilised in 1% $AgNO_3$ for 2 min then rinsed in 5% NaCl for 1 min. A final wash in sterile distilled water for 2 min was undertaken to remove any residual silver cations. Fragments were cultured as a central inoculum on half-strength Potato Dextrose Agar at 28° C for 7 days prior to identification.

*Colletotrichum gloeosporioides* (Penz.) Penz. and Sacc. was isolated from all leaf fragments with leaf spots. Culture of unblemished fragments did not result in any fungal growth. *Colletotrichum* is one of the most important genera of plant pathogenic fungi worldwide[15] and can affect stems, shoots, fruit, pods, flowers and leaves[16]. It has not been isolated from failed sea turtle eggs and so it seems unlikely that the *P. grandis* forest of Heron Island is hosting fungi likely to have an adverse effect on sea turtle nests.

R. Shivas, Queensland Department of Primary Industries, is thanked for the identification of *C. gloeosporioides*.

* S. D. Phillott (unpub.)

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VOL. 125, PART 2

# A COMPARISON OF MACROINVERTEBRATE COMMUNITIES IN THREE SOUTH AUSTRALIAN STREAMS WITH REGARD TO REINTRODUCTION OF THE PLATYPUS

*By Nicholas J. Souter*† & William D. Williams**

## Summary

Souter, N. J. & Williams, W. D. (2001) A comparison of macroinvertebrate communities in three South Australian streams with regard to reintroduction of the platypus. Trans. R. Soc. S. Aust. 125(2), 71-82, 30 November, 2001.

The macroinvertebrate benthos of Scott Creek, an intermittent stream in the Mt. Lofty Ranges, was assessed to determine whether it could sustain a population of platypus (Ornithorhynchus anatinus), a species that has been locally extinct for about 100 years. The benthic fauna was compared to that of Rocky River and Breakneck River, two streams on Kangaroo Island where platypus have been introduced. Little difference was observed in the abundance and biomass of macroinvertebrates in the three streams, suggesting that Scott Creek in common with the two island streams contracts to pools in late summer/early autumn where the platypus populations are limited by this habitat truncation. Further assessment is needed of the physical suitability of Scott Creek for platypus reintroduction (e.g. consolidated banks, over-hanging plants, permanent pools) and the risk of predation by foxes.

Key Words: Macroinvertebrates, platypus, reintroduction, Onkaparinga River, Mt. Lofty Ranges, Kangaroo Island.

*Transactions of the Royal Society of S. Aust.* (2001), **125**(2), 71-82

# A COMPARISON OF MACROINVERTEBRATE COMMUNITIES IN THREE SOUTH AUSTRALIAN STREAMS WITH REGARD TO REINTRODUCTION OF THE PLATYPUS

by NICHOLAS J. SOUTER*† & WILLIAM D. WILLIAMS*

## Summary

SOUTER, N. J. & WILLIAMS, W. D. (2001) A comparison of macroinvertebrate communities in three South Australian streams with regard to reintroduction of the platypus. *Trans. R. Soc. S. Aust.* **125**(2), 71-82, 30 November, 2001.

The macroinvertebrate benthos of Scott Creek, an intermittent stream in the Mt Lofty Ranges, was assessed to determine whether it could sustain a population of platypus (*Ornithorhynchus anatinus*), a species that has been locally extinct for about 100 years. The benthic fauna was compared to that of Rocky River and Breakneck River, two streams on Kangaroo Island where platypus have been introduced. Little difference was observed in the abundance and biomass of macroinvertebrates in the three streams, suggesting that Scott Creek does produce a sufficient food supply. The resource may be marginal, however, as Scott Creek in common with the two island streams contracts to pools in late summer/early autumn where the platypus populations are limited by this habitat truncation. Further assessment is needed of the physical suitability of Scott Creek for platypus reintroduction (e.g. consolidated banks, over-hanging plants, permanent pools) and the risk of predation by foxes.

KEY WORDS: Macroinvertebrates, platypus, reintroduction, Onkaparinga River, Mt Lofty Ranges, Kangaroo Island.

## Introduction

The last reliable record of a platypus (*Ornithorhynchus anatinus* (Shaw)) in the Mt Lofty Ranges, South Australia, was a carcass found after a flood in the River Torrens in 1892 (Hale & Somerville 1942). Before European settlement, the River Torrens, Onkaparinga River and other regional streams contracted to pools in summer and provided a marginal habitat for platypus (Grant 1992; Grant & Denny[1]). Pollution, river regulation, agriculture, forestry and urban development may have contributed to the local extinction of the platypus. Predation by the fox (*Canis (Vulpes) vulpes* L.) and other introduced animals is probably also significant.

Reintroduction provides a valuable tool in the management of vulnerable species. A programme of platypus reintroduction into the Mt Lofty ranges would expand the range of the species and enable the collection of information on the ecology of the platypus in marginal areas. A possible site for platypus reintroduction is Scott Creek, an Onkaparinga tributary that is partly within a conservation park and a protected SA Water catchment.

As a first step toward an assessment of habitat suitability for platypuses, we investigated the potential food supply i.e. benthic macroinvertebrates (cf. Grant & Carrick 1978; Faragher *et al.* 1979; Grant 1982, 1995; Griffith *et al.* 1989; Kleiman 1989). The availability and productivity of benthic macroinvertebrates, upon which platypuses feed, is believed to be the main factor limiting platypus abundance (Grant & Carrick 1978; Faragher *et al.* 1979; Grant 1995). Platypuses are opportunistic carnivores, generally selecting invertebrates in direct proportion to their abundance in the benthos (Faragher *et al.* 1979; Grant 1982). Faragher *et al.* (1979) compared quantitative macroinvertebrate samples collected from pools (dredge netting) and riffles (surber sampling) with the contents of platypus cheek pouches and found that the most abundant animals in the benthos were most abundant in the platypuses' cheek pouches, with some selection for larger invertebrates and selection against smaller ones. We compared the macroinvertebrate benthos of Scott Creek with that in Rocky River and Breakneck River on Kangaroo Island, where platypuses were introduced successfully between 1929 and 1946 (Grant & Denny[1]).

Benthic samples were collected in autumn and spring as they are times of stress for the platypus. Early autumn generally sees a considerable reduction in platypus habitat on Kangaroo Island as the two rivers are reduced to a string of water holes (Grant & Denny[1]). This results in widespread dispersal and mortality of juvenile platypuses (Grant & Denny[1]),

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[1] GRANT, T. R. & DENNY, M. J. S. (1991) Distribution of the platypus (*Ornithorhynchus anatinus*) in Australia with guidelines for management. Australian National Parks and Wildlife Service, Canberra (unpubl.).

Spring is seen as the harshest season for platypuses (Grant 1995) as late winter and early spring rainfall cause flooding and scouring of feeding areas and an increase in flow makes feeding difficult. At the end of winter platypuses are in poor physical condition (Grant & Dawson 1976; Grant 1995), with juvenile males being the most affected as they possess negligible reserves of body fat (Hurlbert & Grant 1983). To make up for this loss of condition platypuses need an abundance of food in the autumn.

## Materials and Methods

*Study Sites*

Scott Creek (35°06′ S, 138°42′ E) is an intermittent, spring-fed stream with a 27 km² catchment that is partly cleared for urban development and pasture (Fig. 1). Three 20-m sites were chosen as representative stream sections in order to sample a broad range of microhabitat types (Table 1). Site SC1 was on the border of Scott Creek Conservation Park, where the stream banks are dominated by the exotic weeping willow (*Salix babylonica* L.). Sites SC2 and SC3 were in the Mt Bold Reservoir catchment, in messmate (stringy-bark) woodland (*Eucalyptus obliqua* L'Hér.). Hydrological records for 1970-94 (Dept Environment & Heritage (DEH), Adelaide, unpub.) indicate a mean annual discharge of 3,501 Ml, with periods of no flow in November (2% of monthly records), December (4%), January (8%), February (16%), March (10%) and April (2%).

Rocky River (35°57′ S, 136°42′ E) drains 190 km² of eucalypt sclerophyll forest in Flinders Chase National Park, Kangaroo Island (Fig. 1). Here, one sampling site (RR1) was chosen (Table 1). Hydrological data for 1974-94 (DEH, unpub.) indicate a mean annual discharge of 17,620 Ml, with no-flow periods in December (4% of monthly records), January (22%), February (62%), March (58%), April (26%) and May (6%).

Breakneck River (35°56′ S, 136°35′ E) drains 92 km² of eucalypt sclerophyll forest in the south-western area of Flinders Chase National Park. Sites BN1 and BN2 were 50 m and 1 km downstream, respectively, from a road crossing (Table 1). Whilst no hydrological data are available, Breakneck River is known to dry to a series of isolated pools at the end of summer (Grant & Denny[1]).

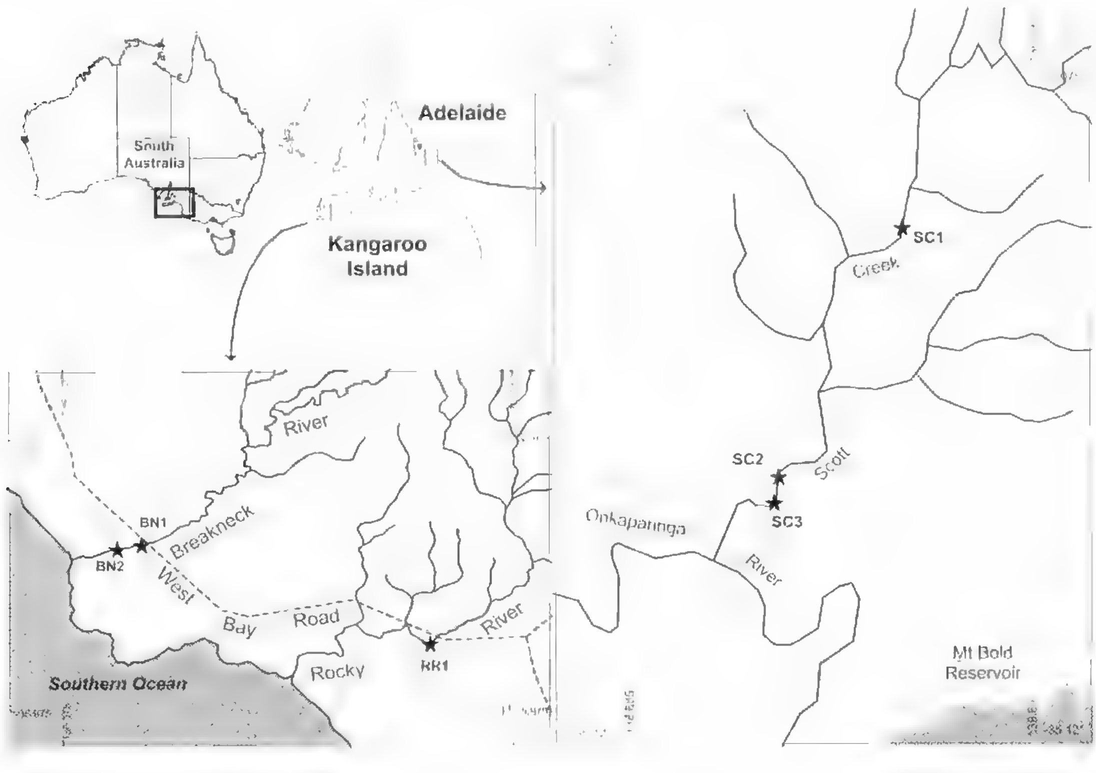


Fig. 1. Sample sites on Scott Creek, Rocky River and Breakneck River.

TABLE 1. *Habitat and morphological parameters from each of the six sites sampled on Scott Creek and the Kangaroo Island streams.*

| | Scott Creek SC1 | SC2 | SC3 | Rocky River RR1 | Breakneck River BN1 | BN2 |
|---|---|---|---|---|---|---|
| Microhabitats sampled for macroinvertebrates | Pool, large woody debris, riffle, run (spring only) | Pool, riffle | Pool, run | Pool, macrophytes | Pool, large woody debris | Pool, large woody debris, riffle, run |
| Riffle substrate | Willow roots | Cobble | - | - | - | Bedrock |
| Pool substrate | Sand, clay, gravel, CPOM | Bedrock/cobble | Bedrock | Silt, CPOM | Sand, CPOM | Silt, CPOM |
| Run substrate | Sand, gravel | - | Cobble | - | - | Bedrock |
| Riparian/emergent vegetation | *Salix babylonica* | *Phragmites. australis*, *Rubus* sp. | *Phragmites australis*, *Rubus* sp. | Grasses | *Melaleuca* sp. | *Melaleuca* sp. |
| Submerged vegetation | - | - | - | *Myriophyllum* sp., *Isolepis fluitans* | - | *Triglochin* sp. |
| Altitude (m) | 240 | 210 | 200 | 50 | 10 | 10 |
| Max depth (m) (autumn) | 1.73 | 0.47 | 1.09 | 0.94 | 0.75 | 0.88 |
| Mean depth (±SD) (m) (autumn) | 0.49 ± 0.43 | 0.22 ± 0.13 | 0.65 ± 0.27 | 0.39 ± 0.24 | 0.37 ± 0.18 | 0.33 ± 0.20 |
| Max width (m) | 9.65 | 3.90 | 7.20 | 9.60 | 3.80 | 5.20 |
| Min width (m) (autumn) | 5.00 | 1.30 | 1.80 | 6.60 | 2.40 | 2.80 |
| Mean (±SD) width (m) (autumn) | 7.03 ± 1.57 | 2.72 ± 0.88 | 4.32 ± 1.90 | 7.98 ± 1.13 | 3.11 ± 0.46 | 4.19 ± 0.71 |
| Undercut banks | Absent | Present | Present | Present | Present | Present |

CPOM (Coarse Particulate Organic Matter) > 1mm

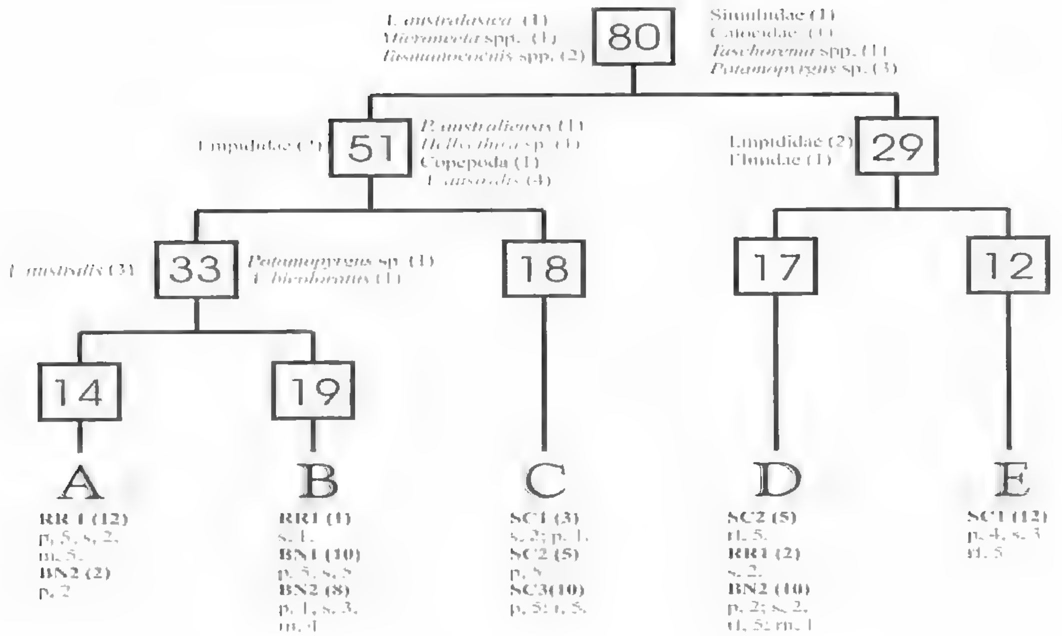


Fig. 2. TWINSPAN dendrogram of samples in autumn. The size of each sample group is shown in square boxes, with indicator species (pseudospecies cut levels in parentheses). The total number of samples from each site is shown, followed by a breakdown of samples from each habitat type (p, pool; s, large woody debris; m, macrophyte; rn, run; rf, riffle). Sample groups are denoted A-E.

*Sampling*

The benthic macroinvertebrate sampling programme was designed with the assumption that platypus will take food in proportion to its abundance in the benthos (Faragher *et al.* 1979). Thus a wide range of microhabitats was sampled for macroinvertebrates using a range of sampling techniques. Five replicate samples were taken from up to five microhabitats at each site (Table 1) in autumn (22 Mar. - 5 Apr.) and spring (28 Aug. - 9 Sept.) 1993. In autumn, 0.1 m deep cores were obtained from pools, riffles and runs with a 0.154 m diameter PVC tube (area 0.018 m², volume 1.8x $10^{-3}$ m³) or, when this was not possible, with a modified 0.18 m² Surber sampler and sieved through a 250 mm mesh dip net. Large woody debris was sampled using a dip net over 0.3 m² for 1 min, and baited 'yabbie traps' also were set. Spring samples were reduced in size to expedite sampling. Species area curves were generated for samples collected in autumn to ensure that no loss of information occurred with reduced sample areas. This change in sample area should not have impacted on the results as no attempt was made to compare temporal differences. (Cores were limited to 0.05 m depth (volume 9.0 x $10^{-4}$ m³) and Surber and dip-net samples were reduced to 0.09 m²). Samples were preserved in 70% ethanol and sieved (2, 1, 0.5 mm mesh) prior to determination of the numbers of organisms per sample. Macroinvertebrates were identified to a level according to their importance as platypus food, following the results of Faragher *et al.* (1979). Where possible, large invertebrates were identified to species. Smaller taxa, those identified in Faragher *et al.* (1979) as less common in the platypus diet, such as chironomids were not identified beyond family. Large invertebrates were selected subjectively on the basis of size and as significance as food with reference to Faragher *et al.* (1979) and are listed in the **Appendix**. Conversions to biomass were made after drying samples (autumn only) at 55° C for 2 days to constant weight. Water temperatures were recorded on site using an alcohol thermometer; conductivity (Radiometer CDM2e meter) and turbidity (Hach Turbidimeter) were determined in the laboratory.

*Data analysis*

All abundance and biomass values were converted to a common unit (number of individuals per 1 m² and grams per 1 m²) prior to analysis. Abundance data were log(x+1) transformed to reduce skew, range-standardised and rendered as a Bray-Curtis distance matrix before Two-Way INdicator SPecies

ANalysis (TWINSPAN) (untransformed pseudo-species were defined by the cut levels of 0, 25, 100, 200 and 1000; default values were employed elsewhere) and ordination by Semi-Strong Hybrid multidimensional scaling (SSH) (PATN: Belbin 1993). Ordination solutions were derived from 500 random starts. A Monte Carlo procedure (MCSSH in PATN) was used to determine whether the three-dimensional SSH ordinations produced reliable patterns. The PATN Principal Axis Correlation procedure (PCC) was used to examine the relationship between ordination vectors and environmental variables (conductivity, current velocity (as a ranked variable: 1, riffle; 2, run; 3, pool), latitude, longitude, turbidity and temperature). PCC correlations were tested for statistical significance ($p < 0.05$) using the PATN Monte Carlo procedure (MCOA) over 100 runs (Faith & Norris 1989). Groups of samples were compared using Analysis of Similarities (Clarke 1993) (ANOSIM in PATN). Samples were grouped according to river, site, microhabitat (large woody debris, pool, riffle, run, macrophyte bed) substratum (large woody debris, sand/gravel, cobbles, bedrock, willow roots, fine silt) and current velocity (still, pool/large woody debris/macrophyte bed; medium, run and fast, riffle).

Median invertebrate abundances, the abundances of large taxa and biomass in pool and riffle samples (see **Appendix**) were compared by Kruskal-Wallis ANOVA as the data were non-normal. Between-site differences were located using Zar's (1984 pp. 199) 'Tukey-type' multiple comparison test, a non-parametric analogue to the Tukey test.

## Results

*Autumn*

Scott Creek yielded 35,295 specimens in 35 samples. Sixty seven taxa, mostly insects (70%), were recorded, with the amphipod *Austrochiltonia australis* (Sayce) being the most abundant taxon in the greatest number of samples collected (Table 2). Rocky River and Breakneck River yielded 9,415 specimens in 45 samples. Fifty six taxa were recorded; these were mainly insects (74%), with chironomids being the most abundant taxon in the largest number of samples collected from both Kangaroo Island rivers (Table 2).

TWINSPAN analysis (Fig. 2) first separated groups correlated with current velocity and site (groups D-E were riffle samples from SC1 and BN2 plus non-riffle samples from RR1 and BN2). The remaining separations were correlated with location (groups A-B from Kangaroo Island; group C from Scott Creek) and site within location. SSH ordination yielded a 3-D model (stress 0.19) (Fig. 3a-c). As the stress of the 3-D model was less than that derived from the MCSSH procedure (stress 0.28) the original

TABLE 2. *Most abundant taxa per sample from Scott Creek, Rocky River and Breakneck River in autumn and spring.*

| Taxon | Autumn Scott Creek (35 samples) | Autumn Rocky River (15 samples) | Autumn Breakneck River (30 samples) | Spring Scott Creek (40 samples) | Spring Rocky River (15 samples) | Spring Breakneck River (30 samples) |
|---|---|---|---|---|---|---|
| *Austrochiltonia australis* | 16 | 4 | | 5 | - | |
| *Potamopyrgus* sp. | 7 | | 3 | 8 | | |
| *Micronecta* spp. | 3 | - | | - | - | |
| Chironomidae | 3 | 11 | 20 | 10 | 1 | 19 |
| Simuliidae | 3 | | 2 | 1 | 2 | 5 |
| Baetidae genus 1 MV sp. 5 | 1 | | | | | |
| *Paratya australiensis* | 1 | | | 1 | | |
| *Sphaerium* sp. | 1 | | | | | |
| Elmidae | | | 4 | | | |
| *Tasmanocoenis* sp. | | | 1 | | - | |
| *Hydroptila scamandra* | - | | | 5 | | |
| *Newmanoperla thoreyi* | | | | | | 6 |
| *Dinotoperla evansi* | - | - | | 2 | 1 | |
| Nematoda | - | | | - | | |
| Oligochaeta | | | | 7 | 7 | |
| Ostracoda | - | | | 1 | | |
| Calocidae | - | - | - | 1 | - | - |
| Chrysomelidae | - | - | | - | 1 | |

The numbers indicate the number of samples in which the given taxon was most abundant ordination is credible. Samples from Scott Creek and the island rivers formed two groups on the third axis, and sites tended to aggregate within these groups. PCC indicated significant correlations for all environmental variables (Table 3). Vectors show two main gradients: an altitude/geography gradient comprising altitude, latitude, longitude, conductivity and temperature and, at right angles on axis three, a current velocity gradient also comprising turbidity (Fig. 3a-c). The altitude/geography gradient delineates the geographically distinct and high altitude Scott Creek samples from the geographically

TABLE 3. *Maximum PCC correlations and significance of environmental variables and sample ordination scores in autumn and spring (* significant at* p *= 0.05; ** significant at* p *= 0.01).*

| Habitat feature | Correlation Autumn | Spring |
|---|---|---|
| Conductivity (mmho) | 0.916** | 0.649** |
| Turbidity (NTU) | 0.519** | 0.345* |
| Water temperature (°C) | 0.872** | 0.552** |
| Current velocity (ranked) | 0.672** | 0.507** |
| Altitude (m) | 0.927** | 0.924** |
| Latitude (decimal degrees) | 0.900** | 0.885** |
| Longitude (decimal degrees) | 0.907** | 0.893** |

closer and lower altitude Kangaroo Island river samples, whilst conductivity and temperature were higher in the Kangaroo Island rivers. The gradient of decreasing current velocity corresponded with an increase in turbidity. This gradient delineated groups of samples from riffle, run and pool sites. ANOSIM results revealed differences between each group of samples analysed: significant differences were located between river ($R$ = 1.240, $p < 0.001$), site ($R$ = 1.356, $p < 0.001$), microhabitat ($R$ = 1.158, $p < 0.001$), substratum ($R$ = 1.226, $p < 0.001$) and current velocity ($R$ = 1.096, $p < 0.001$) sample groups.

Differences in median total macroinvertebrate abundance in the three streams were not significant for microhabitats within and between sites ($H_7$ = 13.72, $p$ = 0.057) (Fig. 4a). There were no significant differences between the numbers of large taxa from habitats within or between sites, with one exception (Fig. 4b). The exception was that the number of large macroinvertebrates in the macrophyte beds at RR1 was greater than that in the run at BN2 ($H_7$ = 21.95, $p$ = 0.003). With regard to biomass there were no significant differences between sites or habitats (Fig. 4c), with the exception that the median biomass from a rocky pool at SC2 was higher than that from a rocky pool and bare sediment pool at BN2 ($H_7$ = 19.62, $p$ = 0.007).

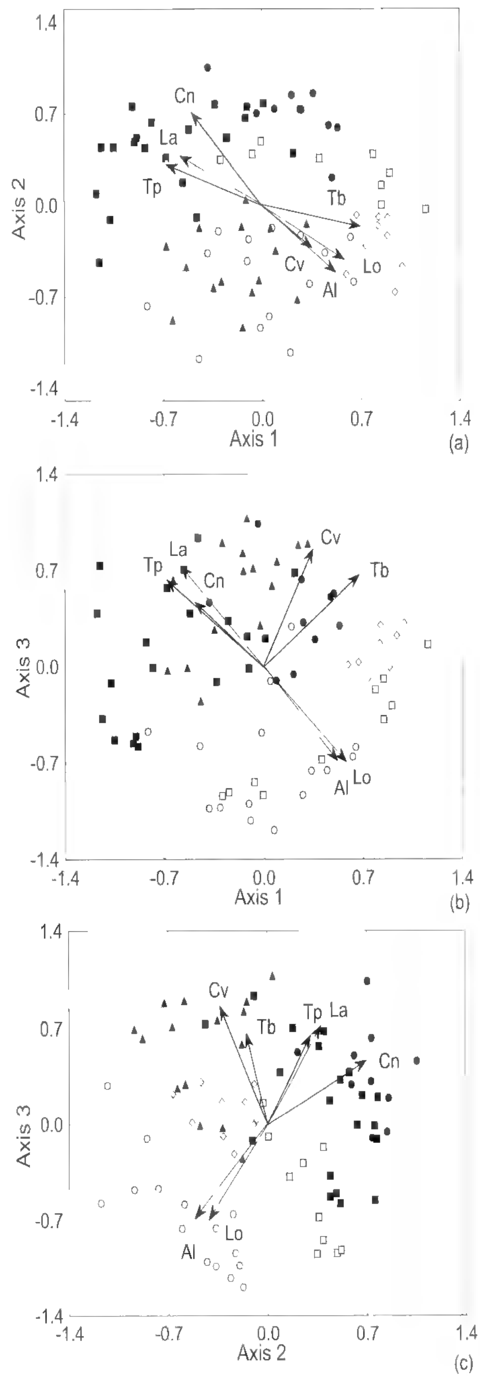


Fig. 3. SSH ordination (a: axis 1 v. 2, b: axis 1 v. 3, c: axis 2 v. 3) for all samples collected during autumn. The site of origin is marked o, SC1; □, SC2; ◊, SC3; ▲, RR1; ●, BN1; ■, BN2. Significant PCC vectors are superimposed on the ordination plot (Al, altitude; Cn, conductivity; Cv, current velocity (ranked); La, latitude; Lo, longitude; Tp, water temperature; Tb, turbidity).

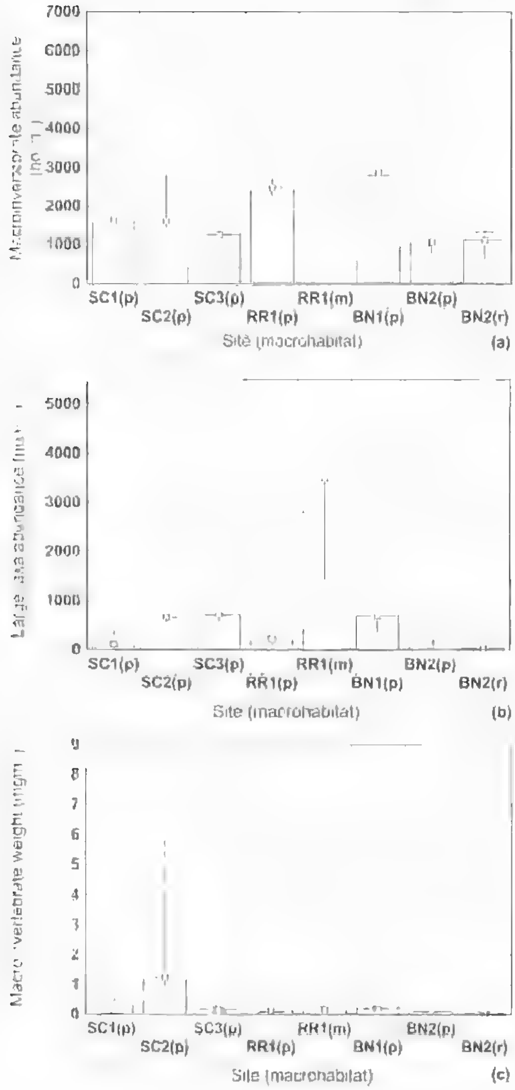


Fig. 4. Major patch type comparison (median ± 75-25 percentile) of autumn samples: (a) abundance, (b) abundance of large organisms, (c) biomass (p, pool; m, macrophyte bed; r, run).

*Spring*

The 40 samples from Scott Creek yielded 13,409 invertebrates in 54 taxa, the majority being insects (68%). Chironomids and the snail *Potamopyrgus* sp. were the most abundant taxa in the largest number of samples (Table 2). A total of 2,964 invertebrates in 44 taxa (81% insects) was collected in 45 samples from Kangaroo Island. Oligochaetes were the most abundant taxon from the largest number of samples collected from Rocky River but chironomids were most abundant in the greatest number of samples collected from Breakneck River (Table 2). Large macroinvertebrates were represented in both Scott Creek and Kangaroo Island samples, indicating that reduced sample sizes in spring were effective in collecting favourable food items.

TWINSPAN analysis indicated seven groups (Fig. 5). The first division separated into groups correlated with current velocity. Pool and macrophyte samples from RR1, BN1 and BN2 (group A-E) separated from the remaining riffle, run, snag and pool samples (group F-G). The remaining divisions broadly separated into groups containing samples of similar location, then site. SSH ordination yielded a 3-D solution (stress 0.19). As the stress of the 3-D model was less than that derived from the MCSSH procedure (stress 0.27) the original ordination is credible. Samples from Scott Creek separated from the two other sites at an angle along Axis 1 (Fig. 6a-b). Sites tended to cluster within these groups (Fig 6a-c). Principal Axis Correlation yielded significant correlations for all environmental parameters (Table 3). The vectors show two main gradients: an altitude/geography gradient and a current velocity gradient. The altitude/geography gradient, comprising altitude, latitude, longitude and water temperature separates the higher altitude/geographically separate Scott Creek samples from the lower altitude and geographically closer Kangaroo Island river samples (Fig. 6a-c). This gradient also corresponds with an increase in water temperature. The current velocity gradient delineates groups of riffle, run and pool samples, whilst an increase in current velocity corresponds with a decrease in conductivity. The orientation of turbidity does not correspond with the other two gradients across the three axes and its level of significance is lower (Table 3). ANOSIM results revealed differences between each group of samples analysed (with the exception of current velocity): significant differences were located between river ($R = 1.233$, $p < 0.001$), site ($R = 1.273$, $p < 0.001$), microhabitat ($R = 1.178$, $p < 0.001$) and substratum ($R = 1.284$, $p < 0.001$) sample groups. Current velocity ($R = 1.018$, $p < 0.16$) was not significant.

Median invertebrate numbers in the macrophyte beds at RR1 and bare sediment from BN1 were greater than those from the rocky pools at BN2 and SC3 ($H_7 = 28.37$, $p = 0.0002$) (Fig. 7a). Otherwise, there was no significant difference between median numbers from habitats within or between sites. The median abundance of large taxa in samples from the three streams was different ($H_7 = 26.40$, $p = 0.0004$) (Fig. 7b). Fewer large organisms occurred in the bare sediment pool at RR1 than the rocky run at SC2 and there were fewer large taxa in the pool at BN2 than either the rocky run at SC2 or macrophyte beds at

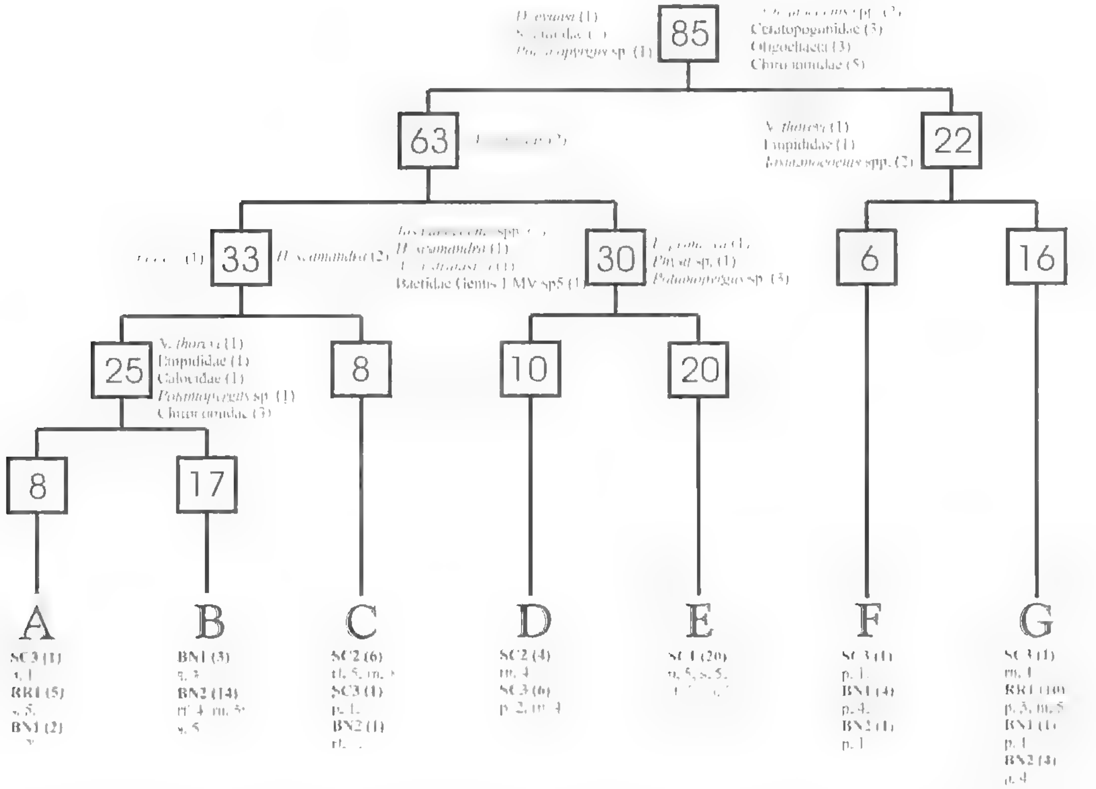


Fig. 5. TWINSPAN dendrogram of samples in spring. The size of each sample group is shown in square boxes, with indicator species (pseudospecies cut levels in parentheses). The total number of samples from each site is shown, followed by a breakdown of samples from each habitat type (p, pool; s, large woody debris; m, macrophyte; m, run; rf, riffle). Sample groups are denoted A-G.

RR1. There was no difference in the abundance of large organisms from other habitats, within or between sites.

## Discussion

There were no major differences in the biomass or the abundance of total fauna or larger taxa in Scott Creek and the Kangaroo Island rivers. This finding suggests that Scott Creek is a potential platypus reintroduction site, based on the available food resource in autumn and spring. However further information is needed on the food resource during a dry year and over a wider area before reintroduction of the platypus into the Scott Creek area is considered.

The key food groups for platypus in the Shoalhaven River, New South Wales, were Trichoptera, Odonata, Diptera and Ephemeroptera (Faragher *et al.* 1979). These are well-represented in Scott Creek, and the decapods *Cherax destructor* Clark and *Paratya australiensis* Kemp also are potential prey (cf. Faragher *et al.* 1979; Krueger *et al.* 1992). The dominant macroinvertebrate in Scott Creek the amphipod, *Austrochiltonia australis*, is another potential food source. In contrast, the Kangaroo Island rivers (and Scott Creek in spring) were dominated by chironomids, considered a less substantial food for platypus by Faragher *et al.* (1979).

The macroinvertebrate community in Scott Creek differed from that in Rocky River and Breakneck River, with samples from similar streams and sites (for example Rocky River and Breakneck River, and sites within Scott Creek respectively) showing greatest affinity to one another. Differences in community structure between Scott Creek and the Island rivers were consistently correlated with a number of river specific habitat and environmental variables, such as altitude, latitude and longitude. Scott Creek and the two Kangaroo Island rivers are geographically distinct (separated by more than 200 km) and differ markedly in altitude and microhabitat types. These three factors have been shown to

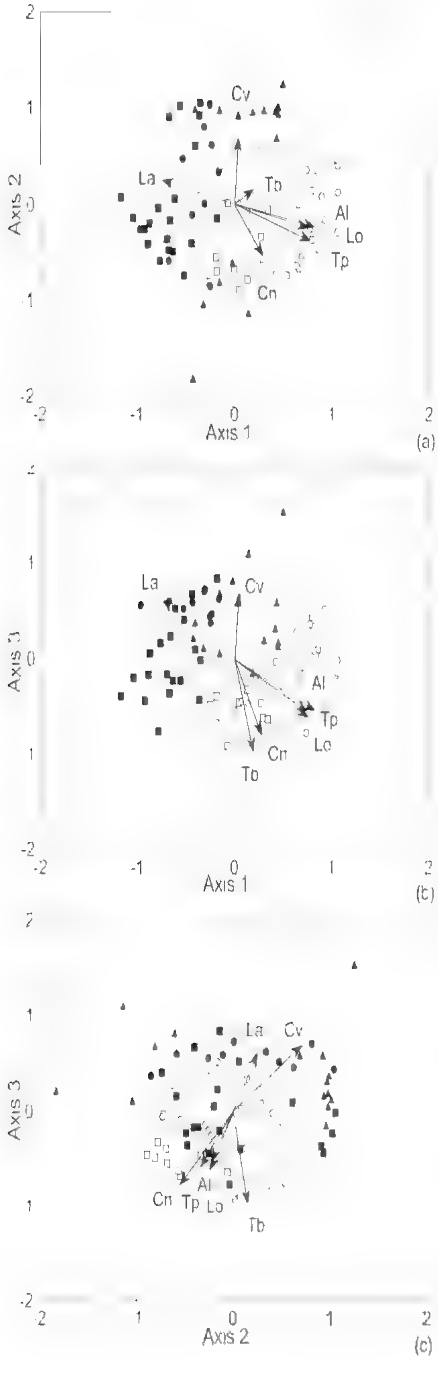


Fig. 6. SSH ordination plot on axes (a) 1 v. 2, (b) 1 v. 3, (c) 2 v. 3 for all samples collected during spring. The site of origin is marked o. SC1; □. SC2; ◊. SC3; ▲. RR1; ●. BN1; ■. BN2. Significant PCC vectors are superimposed on the ordination plot (Al, altitude; Cn, conductivity; Cv, current velocity (ranked); La, latitude; Lo, longitude; Tp, water temperature; Tb, turbidity).

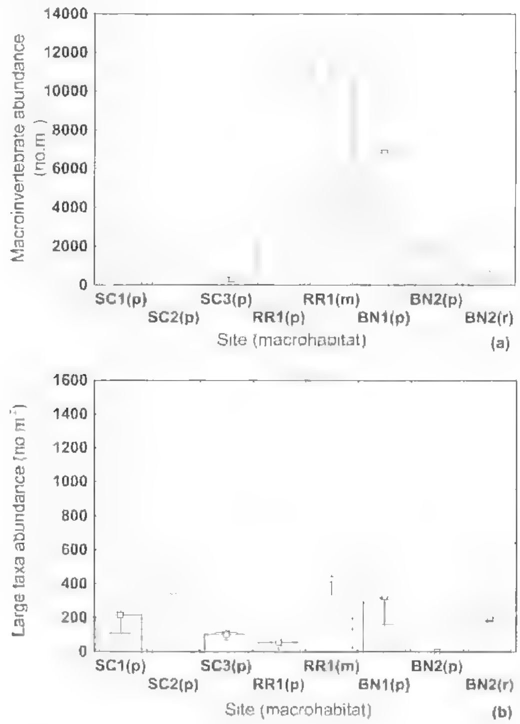


Fig. 7. Major patch type comparison (median ± 75-25 percentile) of spring samples: (a) abundance, (b) abundance of large organisms, (p, pool; m, macrophyte bed; r, run).

explain differences in aquatic macroinvertebrate structure of spatially distinct sites (cf. Corkum 1992; Marchant *et al.* 1994; Marchant *et al.* 1999).

Despite the differences in community structure between streams, samples from similar microhabitats and substrates were similar. This similarity was also related to differences in current velocity. Autumn riffle samples from Scott Creek and Breakneck River showed more similarity to one another than to other microhabitats at the same sites (cf. Delucchi 1988; Boulton & Lake 1992). Samples from Rocky River and Breakneck River were more similar to one another than to samples from Scott Creek but were also different from one another.

The two island stream communities are likely to differ from those of Scott Creek since they have been subjected to prolonged platypus predation. In this study, chironomids and other small organisms dominated in the streams subject to platypus predation and larger organisms dominated in Scott Creek. There was little difference in total faunal abundance or biomass between the three sites, suggesting that platypuses may not have a great influence in that regard. It is likely, however, that reintroduction of platypuses into Scott Creek would reduce the density and abundance of larger organisms, so that the benthic fauna in Scott Creek would become more like that in the two island rivers. There are also likely to be differences in predation pressure between the three streams, due to differences in the fish fauna. Predation by fish, for example, causes behavioural changes in lotic macroinvertebrates (Cowan & Peckarsky 1994; Kolar & Rahel 1993; Tikkanen *et al.* 1996) and reduces abundance (Closs 1996) and density (Dudgeon 1993; McIntosh & Townsend 1994). Brook trout may selectively reduce the biomass and density of large organisms (e.g. Ephemeroptera, Trichoptera), promoting smaller ones (e.g. Chironomidae) (Bechara *et al.* 1992, 1993). Scott Creek supports populations of climbing galaxias (*Galaxias brevipinnis* Günther), redfin (*Perca fluviatilis* L.), brown trout (*Salmo trutta* L.) and gambusia (*Gambusia affinis holbrooki* (Girard)) (M. Hammer, Adelaide University, pers. comm. 2001). In Rocky River, common galaxias (*G. maculatus* Jenyns) and climbing galaxias have been recorded (SA Museum data), whilst according to Glover (1982) rainbow trout (*Oncorhynchus mykiss* (Richardson)) and brown trout (*S. trutta*) are potentially present having been introduced into farm dams on Kangaroo Island in the 1950s. It is not possible to evaluate further the potential food resource in Scott Creek without quantifying the impact of platypus predation on the island rivers, but it does appear likely that platypuses would not be excluded from Scott Creek for want of food.

The three sections of Scott Creek investigated in this study are insufficient to evaluate fully Scott Creek in terms of platypus habitat. As the home range of a platypus has been estimated to be between 1-2.3 km (Grant 1992), 0.33-2.28 km (Serena 1993) and 2.9-7.0 km with one male travelling up to 15 km (Gardner & Serena 1995) a wider assessment of Scott Creek and surrounding water bodies is required to determine if enough suitable food and habitat are present to support a viable platypus population. The continued flow of both Scott Creek and the two Kangaroo Island rivers at the time of autumn sampling did not allow for an assessment of the food resource when the habitat was at its most marginal. Before reintroduction can be further considered an expanded study of Scott Creek and surrounding water bodies is required at a time of no flow. This survey is required to confirm the presence of consolidated banks, overhanging vegetation, adequate food resources and the deep permanent pools favoured by platypuses. The potential threat of predation by foxes must also be assessed before reintroduction is considered.

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## Appendix

Macroinvertebrate species, assignments of "large" organisms (designated by *), site (SC Scott Creek; RR Rocky River; BN Breakneck River) and season (a, autumn; s, spring) in 1993.

| Major Group | Large | Taxon | Site/Season |
|---|---|---|---|
| **TEMNOCEPHALIDEA** | | *Temnocephala* spp | SCas, BNas |
| **TURBELLARIA** | | | |
| Dugesiidae | | *Cura pinguis* Weiss, 1910 | SCas, RRs |
| **NEMATODA** | | Unidentified spp. | SCas, RRs, BNas |
| **ANNELIDA** | | | |
| OLIGOCHAETA | | Unidentified spp. | SCas,RRas, BNas |
| HIRUDINEA | | Unidentified spp. | SCas |
| **MOLLUSCA** | | | |
| GASTROPODA | | | |
| Ancylidae | | *Ferrissia* spp. | SCas, RRa, BNas |
| Hydrobiidae | | *Potamopyrgus* sp. | SCas, RRas, BNas |
| Planorbidae | | *Physa* sp. | SCas, BNas |
| | | *Isidorella* sp. | SCas, BNa |
| BIVALVIA | | | |
| Sphaeriidae | | *Sphaerium tasmanicum* (Tenison-Woods, 1876) | SCas |
| **HYDRACARINA** | | Unidentified spp. | SCa, RRa, Bna |
| **CRUSTACEA** | | | |
| AMPHIPODA | | | |
| Ceinidae | * | *Austrochiltonia australis* (Sayce, 1901) | SCas, RRas, BNa |
| DECAPODA | | | |
| Atyidae | * | *Paratya australiensis* Kemp, 1917 | SCas |
| Parastacidae | * | *Cherax destructor* Clark, 1936 | SCas, RRa |
| OSTRACODA | | Unidentified spp. | SCas, RRas, BNas |

| | | |
|---|---|---|
| COPEPODA | Unidentified spp. | SCas, RRa, BNa |
| CLADOCERA | Unidentified spp. | SCa, BNa |
| ISOPODA | | |
| Janiridae | Unidentified sp. | SCas, BNs |
| **INSECTA** | | |
| DIPTERA | | |
| Chironomidae | Unidentified spp. | SCas, RRas, BNas |
| Simuliidae | Unidentified spp. | SCas, RRas, BNas |
| Ceratopogonidae | Unidentified spp. | SCas, RRas, BNas |
| Empididae | Unidentified spp. | SCas, RRa, BNas |
| Tipulidae | Unidentified spp. | SCas, RRas, BNas |
| Muscidae | Unidentified spp. | SCa, RRs, BNs |
| Stratiomyidae | Unidentified spp. | SCas, BNa |
| Culicidae | Unidentified spp. | SCa |
| EPHEMEROPTERA | | |
| Baetidae | Baetidae Genus 1 MV sp5 | SCas |
| | *Centroptilum elongatum* Suter, 1986 | SCa, RRas, BNas |
| | *Cloeon* sp. | SCas |
| Leptophlebiidae | *Atalophlebia australasica* (Pictet, 1845) | SCas, RRa, BNas |
| | *Nousia inconspicua* (Eaton, 1871) | SCas, RRas, BNas |
| Caenidae | *Tasmanocoenis* spp. | SCas, RRas, BNas |
| TRICHOPTERA | | |
| Calocidae | Unidentified spp. | SCas, RRa, BNas |
| Leptoceridae | *Triplectides* spp. | SCas, RRas, BNas |
| | *Oecetis* spp. | SCas, RRas, BNas |
| | *Notalina* spp. | SCs |
| Calamoceratidae | *Anisocentropus bicoloratus* (Martynov, 1914) | SCas, BNas |
| Atriplectidae | Unidentified spp. | BNas |
| Ecnomidae | *Ecnomus* spp. | SCas, RRa, BNa |
| Hydroptilidae | *Hellyethira* spp. | SCas, RRa, BNa |
| | *Orphninotrichia* sp. | SCa |
| | *Oxyethira* sp. | RRa, BNas |
| | *Hydroptila scamandra* Neboiss, 1977 | SCas, BNas |
| Hydropsychidae | *Cheumatopsyche* spp. | SCas |
| Hydrobiosidae | *Apsilochorema* sp. | BNa |
| | *Ulmerochorema* sp. | SCa |
| | *Taschorema* species complex. | SCas, RRas, BNas |
| COLEOPTERA | Unidentified sp. (larvae) | SCa |
| Elmidae | Unidentified spp. (larvae) | SCas, BNas |
| Dytiscidae | *Antiporus* sp. | SCas |
| | *Necterosoma* sp. | SCa |
| | *Sternopriscus multimaculatus* (Clark, 1862) | SCs, RRa, BNa |
| | Unidentified sp. | SCa |
| Gyrinidae | Unidentified sp. (adults) | RRa |
| Scirtidae | Unidentified spp. (larvae) | SCas, RRas, BNas |
| Chrysomelidae | Unidentified sp. | RRs |
| Hydrophilidae | Unidentified spp. (adults, larvae) | SCas, BNa |
| PLECOPTERA | Unidentified sp. | SCas, RRa, BNas |
| Gripopterygidae | *Dinotoperla evansi* Kimmins, 1951 | SCas, RRs, BNas |
| | *Newmanoperla thoreyi* (Banks, 1920) | SCas, RRs, BNas |
| | *Leptoperla primitiva* McLellan, 1971 | SCs, RRs |
| | *Illiesoperla mayi* (Perkins, 1958) | SCs, RRs, BNs |
| Notonemouridae | *Austrocerca tasmanica* (Tillyard, 1924) | SCas, BNa |
| HEMIPTERA | | |
| Mesoveliidae | *Mesovelia* spp. | SCas, RRa, BNs |
| Corixidae | *Micronecta* spp. | SCas, RRas, BNa |
| | *Sigara* sp. | SCa, RRa |
| Veliidae | Unidentified spp. | SCas, RRas |
| Notonectidae | *Anisops* sp. | SCa, RRa, BNa |
| ODONATA | | |
| Coenagrionidae | *Ischnura heterosticta* (Burmeister, 1839) | SCas, RRa |
| Corduliidae | *Hemicordulia tau* (Selys, 1871) | SCa, RRa, BNa |
| Aeshnidae | *Austroaeschna parvistigma* (Selys, 1883) | SCas |
| | *Austroaeschna unicornis unicornis* (Martin, 1901) | SCa, RRa, BNas |
| | *Hemianax papuensis* (Burmeister, 1839) | BNa |
| Gomphidae | *Austrogomphus ochraceus* (Selys, 1869) | RRa, BNa |
| | *Austrogomphus* sp. | SCa, RRa, BNas |
| LEPIDOPTERA | | |
| Pyralidae | Unidentified spp. | RRa |

# TAXONOMY AND BIOLOGY OF A NEW SPECIES OF ZAPHANERA (HEMIPTERA: ALEYRODIDAE) AND ITS ASSOCIATION WITH THE WIDESPREAD DEATH OF WESTERN MYALL TREES, ACACIA PAPYROCARPA, NEAR ROXBY DOWNS, SOUTH AUSTRALIA

*By P. T. Bailey*, J. H. Martin†, J. S. Noyes† & A. D. Austin‡**

## Summary

Bailey, P. T., Martin, J. H., Noyes, J. S. & Austin, A. D. (2001) Taxonomy and biology of a new species of Zaphanera (Hemiptera: Aleyrodidae) and its association with the widespread death of western myall trees, Acacia papyrocarpa, near Roxby Downs, South Australia. Trans. R. Soc. S. Aust. 125(2) 83-96, 30 November, 2001.

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Key Words: Zaphanera, Zarhopaloides, Acacia papyrocarpa Bentham, western myall whitefly, western myall tree, outbreak, tree death.

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by P. T. BAILEY[*], J. H. MARTIN[†], J. S. NOYES[†] & A. D. AUSTIN[‡]

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An outbreak of western myall whitefly, a new species of *Zaphanera* (Hemiptera: Aleyrodidae), is associated with dieback and death of western myall trees, *Acacia papyrocarpa* Bentham, in a desert area of about 10,000 km$^2$ in South Australia. Both young and mature trees up to several hundred years old are affected. Death of foliage appears to be related to large numbers of the whitefly feeding on phyllodes. A new species of the parasitoid *Zarhopaloides* (Hymenoptera: Encyrtidae) emerged from whitefly pupae and appears to be the first encyrtid authenticated as a true parasitoid of aleyrodids. Possible causes of this outbreak are discussed and include (1) a temporary parasitoid asynchrony with its host population, (2) the possibility that western myall whitefly has been newly-introduced to the area on another plant host and has adapted to western myall trees and (3) that the outbreak is symptomatic of a widespread decline in the health of trees. All life-history stages of the new species of *Zaphanera* and the new species of the parasitoid *Zarhopaloides* are described.

KEY WORDS: *Zaphanera*, *Zarhopaloides*, *Acacia papyrocarpa* Bentham, western myall whitefly, western myall tree, outbreak, tree death.

## Introduction

Western myall, *Acacia papyrocarpa* Bentham, is a desert adapted tree of chenopod shrublands on calcareous soils in the 150-300 mm (predominantly winter) rainfall zones of northern Spencer Gulf, along the margins of the Nullarbor Plain of South Australia, and in the Eastern Goldfields of Western Australia. Much of this area is used for grazing sheep and cattle for which the trees provide shelter. Western myall shares the eastern parts of its range with mulga, *Acacia aneura* F. Muell., to form a mixed species woodland.

Western myall trees are slow-growing and may reach 5-6 m before becoming recumbent (Lange & Sparrow 1992). Age estimates of mature trees vary from 250 years (Coleman *et al.* 1996[1]) to 350+ years (Ireland 1997[2]). Foliar growth flushes are produced by the tree during summer (November to February) and appear to be independent of rainfall (Ireland 1997[2])

This paper describes an outbreak of an apparently native whitefly species in the genus *Zaphanera* on western myall which has killed trees over a wide area of north-eastern South Australia. There is no historical evidence of previous outbreaks of this species on western myall trees anywhere in Australia (nor of any other insect capable of killing so many trees so quickly). We are not aware of previous reports of any whitefly species causing widespread death of perennial trees. Both the whitefly and its encyrtid wasp parasitoid are described as new and possible reasons for the outbreak are discussed.

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[1] COLEMAN, D., IRELAND, C. & WEST, N. E. (1996) The lifespan of western myall (*Acacia papyrocarpa* Benth.). "Rangelands in a sustainable biosphere". Proceedings of the Fifth International Rangeland Congress Salt Lake City, Utah, USA 23-28 July, 1995 Volume 1 contributed presentations. 1996, 99-100. (Society for Range Management, Denver, Colorado, USA) (unpub.).

[2] IRELAND, C. (1997). Sustaining the western myall woodlands: ecology and management. PhD Thesis, Department of Environmental Science and Rangeland Management, Adelaide University (unpub.).

## Materials and Methods

### *Taxonomy*

Terminology for whitefly morphology follows that of Martin (1999) and that for the encyrtid parasitoid is after Noyes & Hayat (1994). The following abbreviations are used for institutions:

ANIC, Australian National Insect Collection, CSIRO Entomology, Canberra;

BMNH, The Natural History Museum, London, UK;

USNM, US National Museum of Natural History, Washington, DC;

WINC, Waite Insect and Nematode Collection, Waite Campus, SA.

The following abbreviations are used in the parasitoid description:
AL - aedeagus length
EL - maximum eye length
EW - maximum eye width
F1-6 - funicle segments 1-6, i.e. the first six segments after the pedicel
FV - minimum frontovertex width
FWL - fore wing length
FWW - fore wing width
GL - gonostylus length
HW - head width
HWL - hind wing length
HWW - hind wing width
MT - mid tibia length
MS - malar space
OCL - minimum distance between posterior ocellus and occipital margin
OL - ovipositor length
OOL - minimum distance between posterior ocellus and eye margin
POL - minimum distance between posterior ocelli
SL - scape length
SW - maximum scape width

*Biology*

The life cycle of western myall whitefly was constructed from ten population samples taken at approximately monthly intervals during September-April and less frequently during May-August over the period December 1999 to December 2000. Whitefly population samples were taken from 20 mature trees, individually marked, just outside Roxby Downs township. At each sampling time, a healthy growing shoot was cut from each tree at approximately 2.5 m height and individually stored in a paper bag. The samples were examined within two days of collection. On each shoot, five sub-terminal mature phyllodes were examined and the number and stage of whiteflies were noted using x 20 magnification under a binocular microscope.

This intensity of sampling yielded estimates of mean numbers of whitefly with the following standard errors: for eggs, 20% of the mean per phyllode, for each of second and third instar larvae, 25% of mean and for the pupal stage, 19% of the mean number per phyllode. First instar (mobile) larvae were rarely observed. The presence of any adults flying around trees was also noted.

During the year 2000, ground surveys along station tracks delimited the extent of the whitefly infestation. Trees with symptomatic dieback were inspected and the presence of a whitefly noted. Non-symptomatic trees were examined in every copse encountered along the route, generally allowing at least 5 km after each positive record before resuming sampling. A tree was chosen 10-20 m away from the track but beyond this, no special sampling scheme was used. On each tree, 50 phyllodes were examined with the aid of a hand lens and, if any stage(s) of whitefly were present, the tree was counted as positive. If no whiteflies were found on the tree examined, a nearby tree was sampled. If this was positive, the site was scored as positive. The site was scored as negative only if no evidence of the whitefly was found on either tree.

***Zaphanera papyrocarpae*** **Martin sp. nov.**
(FIGS 1-4, 7-17)

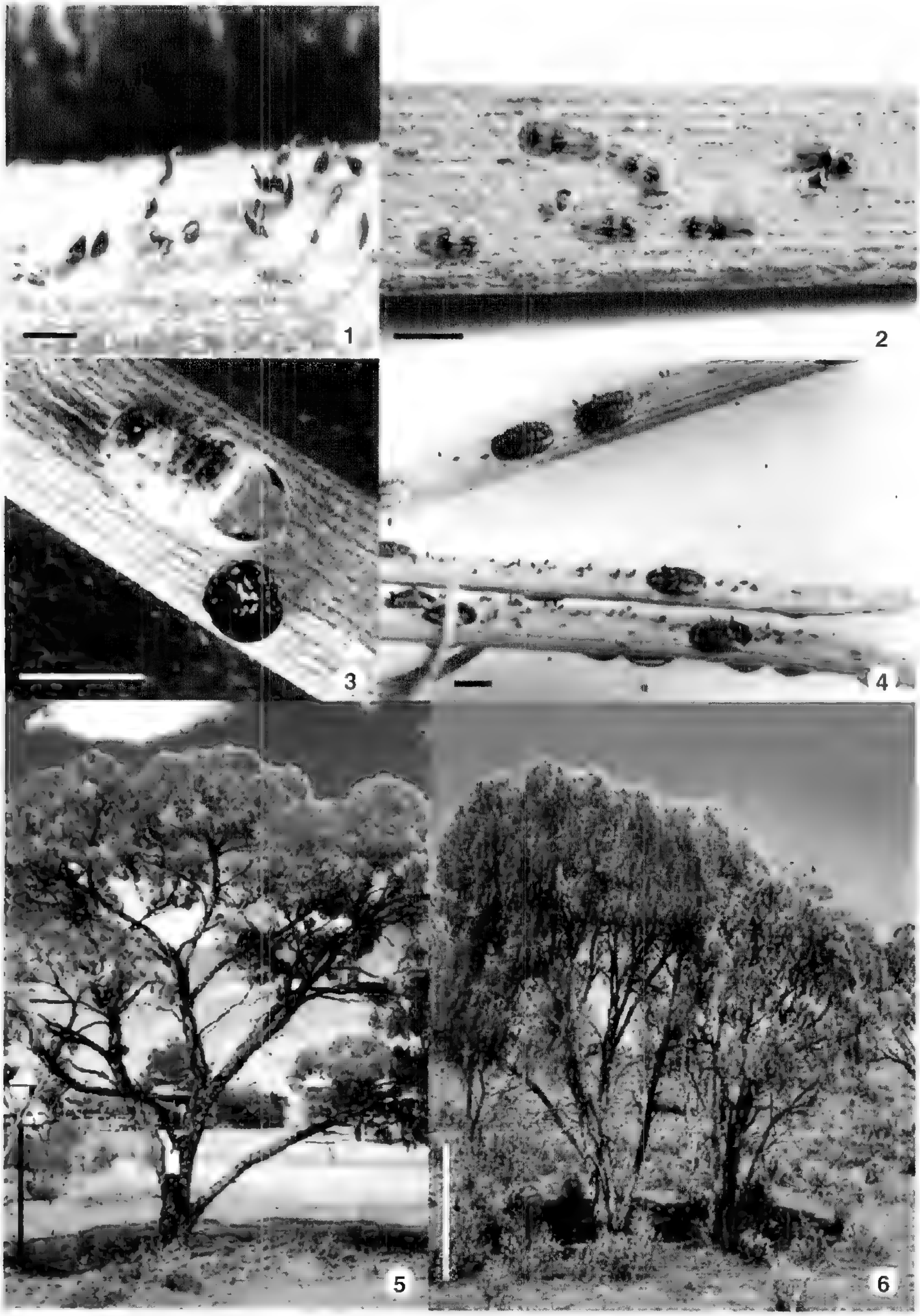
*Holotype*: ♂ puparium, Billakilina Station, 30° 16' S, 136° 17' E, South Australia, on phyllodes of *Acacia papyrocarpa*, 26.iv.2000 (J. H. Martin 7406) (slide-mounted, ANIC).

*Paratypes*: South Australia (all slide-mounted): 9 ♂♂ (puparia), 16 ♀♀ (puparia) same data as holotype (ANIC, BMNH, USNM, WINC); 3 ♂♂ (puparia), 6 ♀♀ (puparia) Roxby Downs township, 27.iv.2000 (J. H. Martin) (BMNH, WINC), 25 puparia, 6 third-instar larvae, 1 second-instar larva, vicinity of Roxby Downs, v.1999 (J. Zwar) (ANIC); 29 puparia, 6 L3/puparium mid-moults, 9 third-instar larvae, 11 first-instar larvae, vicinity of Roxby Downs 20.x.1999 (P. Bailey) (BMNH, WINC); 14 puparia, 2 L3/puparium mid-moults, 4 third-instar larvae, vicinity of Roxby Downs 11.i.2000 (J. Hardy) (BMNH, WINC); 11 adult ♂♂, 9 adult ♀♀, vicinity of Roxby Downs, 14.ii.2000 (P. Bailey) (BMNH); 1 L3/puparium mid-moult, 6 third-instar larvae, 37 second-instar larvae, 5 first-instar larvae, Roxby Downs township, 25.iv.2000 (J. H. Martin) (BMNH).

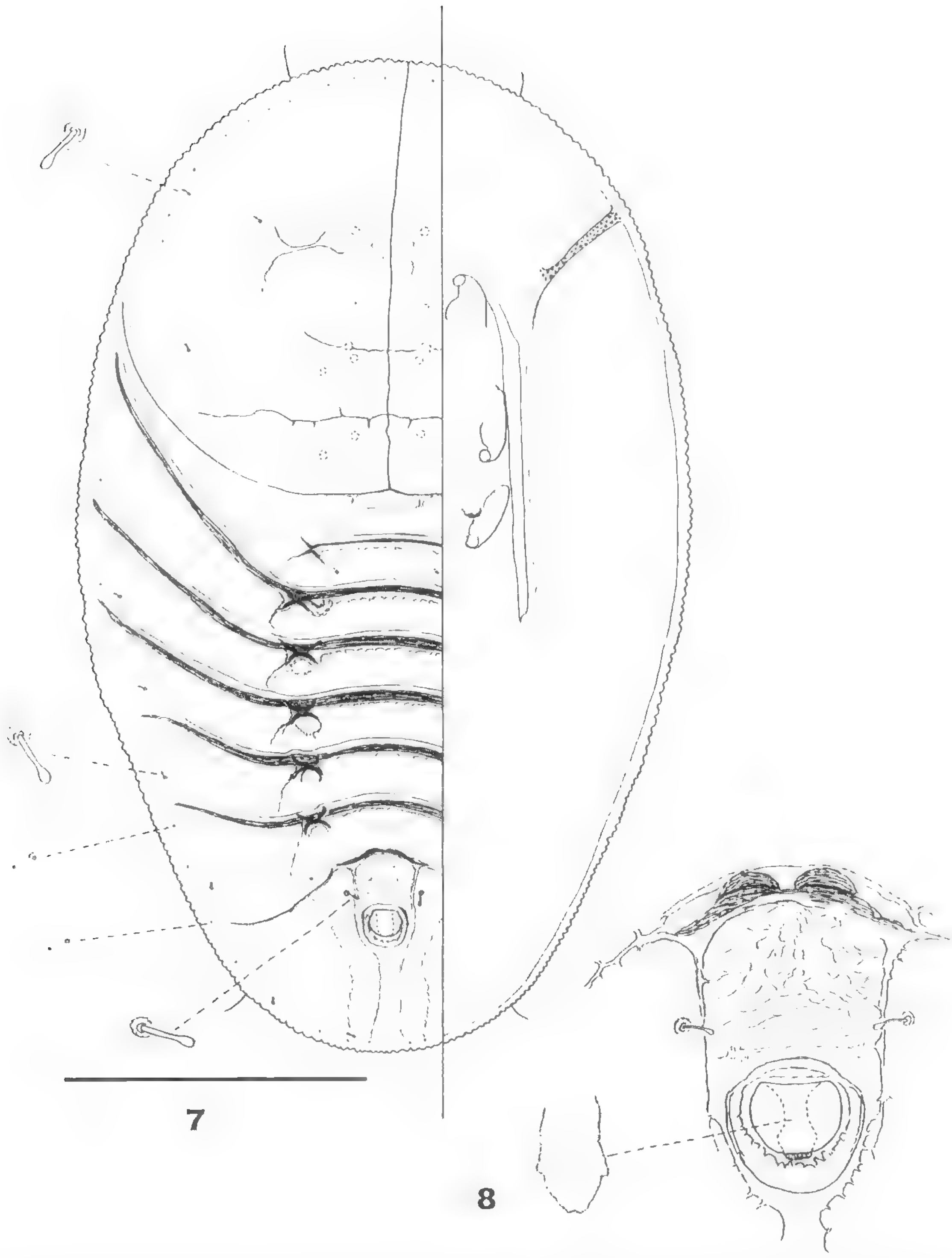
*Other material*: A large amount of dry material of all larval stages from the above collection sites is held in BMNH and WINC.

*Puparium* (Figs 3, 4, 7, 8)

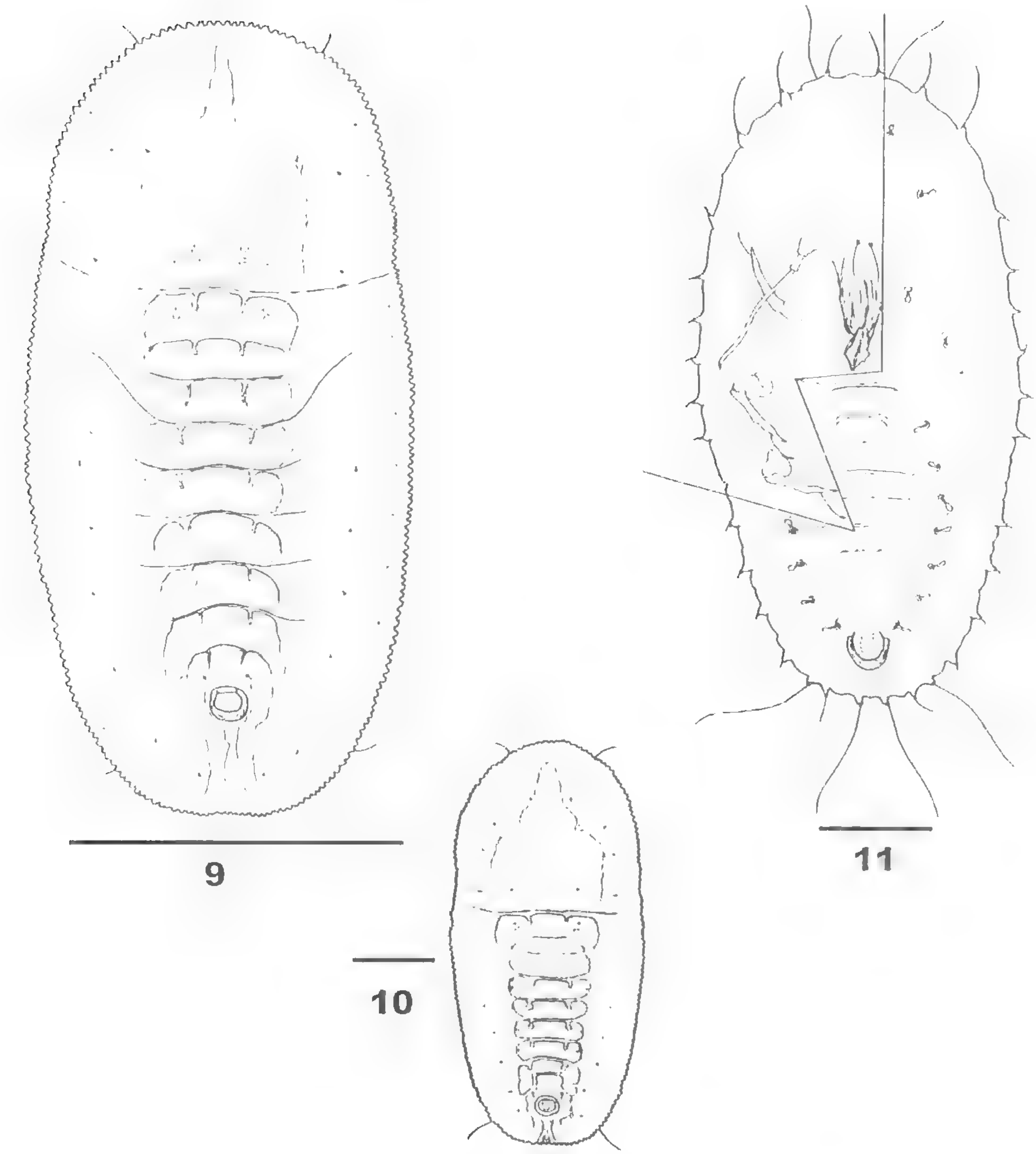
Shortly after the L3/L4 moult shining black, almost flat, but with increasing maturity becoming markedly convex and developing covering of sparse greyish meal (Fig. 3); entire cephalothorax falling away upon emergence of adults (Fig. 3); sexually dimorphic, male puparia 1.42-1.57 mm long, 0.81-0.96 mm wide, widest opposite confluence of longitudinal and transverse moulting sutures (Fig. 7); antennal apices underlying median part of abdominal segment II/III (n=16); female puparia 1.72-1.95 mm x 1.05-1.18 mm, widest abdominally; antennal apices terminating between middle and hind legs (n=14); puparia of both sexes 1.50-1.80 x as long as wide; margin crenulate throughout, typically 6-8 rounded teeth occupying 0.1 mm of abdominal



Figs 1-6. Life history stages and damage of western myall whitefly, *Zaphanera papyrocarpae* Martin sp. nov. 1. Eggs on a phyllode of western myall. 2. One second instar (on left) and third instar larvae on a phyllode. 3. Adult female emerging from puparium. 4. Eggs and pupae encrusting phyllodes. 5. Damage by *Z. papyrocarpae*. A western myall tree in Roxby Downs township with early symptoms of dieback associated with *Z. papyrocarpae* on phyllodes (this tree died six months later). 6. Dead (left) and dying (right) western myall trees in pastoral lands of South Australia. Scale bars = 0.5 mm, 1; 1 mm, 2-4; 1 m, 5, 6.




Figs 7, 8. *Zaphanera papyrocarpae* Martin sp. nov., puparium. 7. Complete puparium with expanded detail of capitate setae and geminate pore/porette pairs. 8. Dorsal detail of vasiform orifice region (drawn from a teneral puparium). Scale bar = 0.5 mm.




Figs 9-11. *Zaphanera papyrocarpae* Martin sp. nov., instars I-III (not drawn to same scale). 9. Third-instar larva, dorsum. 10. Second-instar larva, dorsum. 11. First-instar larva. Scale bars = 0.5 mm, 9; 0.1 mm, 10, 11.

margin; teeth rather irregular but not modified at caudal and thoracic tracheal openings at margin; anterior and posterior marginal setae present; dorsal chaetotaxy difficult to discern in mature puparia; all dorsal setae short, capitate; single pair of 8th abdominal setae placed anterior and slightly lateral to vasiform orifice; abdomen usually with 6 outer submarginal pairs, cephalothorax usually with a single outer submarginal pair and 2 subdorsal pairs of setae (Fig. 7), but cephalic (submedian) setae absent; dorsum with longitudinal moulting suture reaching puparial margin; transverse moulting sutures curving anterolaterally and reaching margin; abdominal segmentation as shown, the intersegmental divisions of abdominal segments II/III to VI/VII exaggerated, thickened, suture-like, all curving sharply anteriad and almost reaching puparial margin; abdominal division VII/VIII less exaggerated but also closely approaching margin, submedian pockets variably marked depending on degree of maturity; abdominal segment VII not reduced in length medially; abdominal rhachis evident, with lateral arms short (not to be confused with long intersegmental divisions); pair of submedian posteriorly directed tubercles on posterior edge of each of abdominal segments I-VI abut with a pair of similar anteriorly directed tubercles on the anterior edge of each of segments II-VII, often appearing as 6 pairs of characteristic darker "X" figures; submedian abdominal depressions present but camouflaged by these tubercles; cephalothoracic equivalents clearly marked by irregular rings of paler markings; submargin with row of tiny pores, seen to be geminate pore/porette pairs only in teneral specimens; similar pores seen in small groups adjacent to submedian depressions; vasiform orifice cordate, slightly elevated posterolaterally, fully occupied by operculum which obscures lingula; in teneral specimens lingula as shown in Fig. 8, without apical setae (characters of vasiform orifice essentially the same throughout larval stages); vasiform orifice about 0.06 mm long in male, 0.07 mm in female, inset from posterior puparial margin by 2.0-3.1 x its own length in male, 3.3-4.1 x in female; caudal furrow defined by shallow ridge to either side but without markings, eyespot markings absent. On venter antennae dimorphic as discussed above, bases placed lateral to fore legs; legs each with apical adhesion pad; middle and hind legs each with tiny basal seta and spine; ventral abdominal setae placed slightly anterior to dorsal 8th abdominal setae; caudal and thoracic tracheal folds present, narrow, paler than adjacent cuticle and punctuated by darker ovoid markings; when venter separated from the dorsum, submedian area seen to be much paler than submargin/subdorsum (a character typical for *Zaphanera*).

*Third-instar larva* (Figs 2, 9)

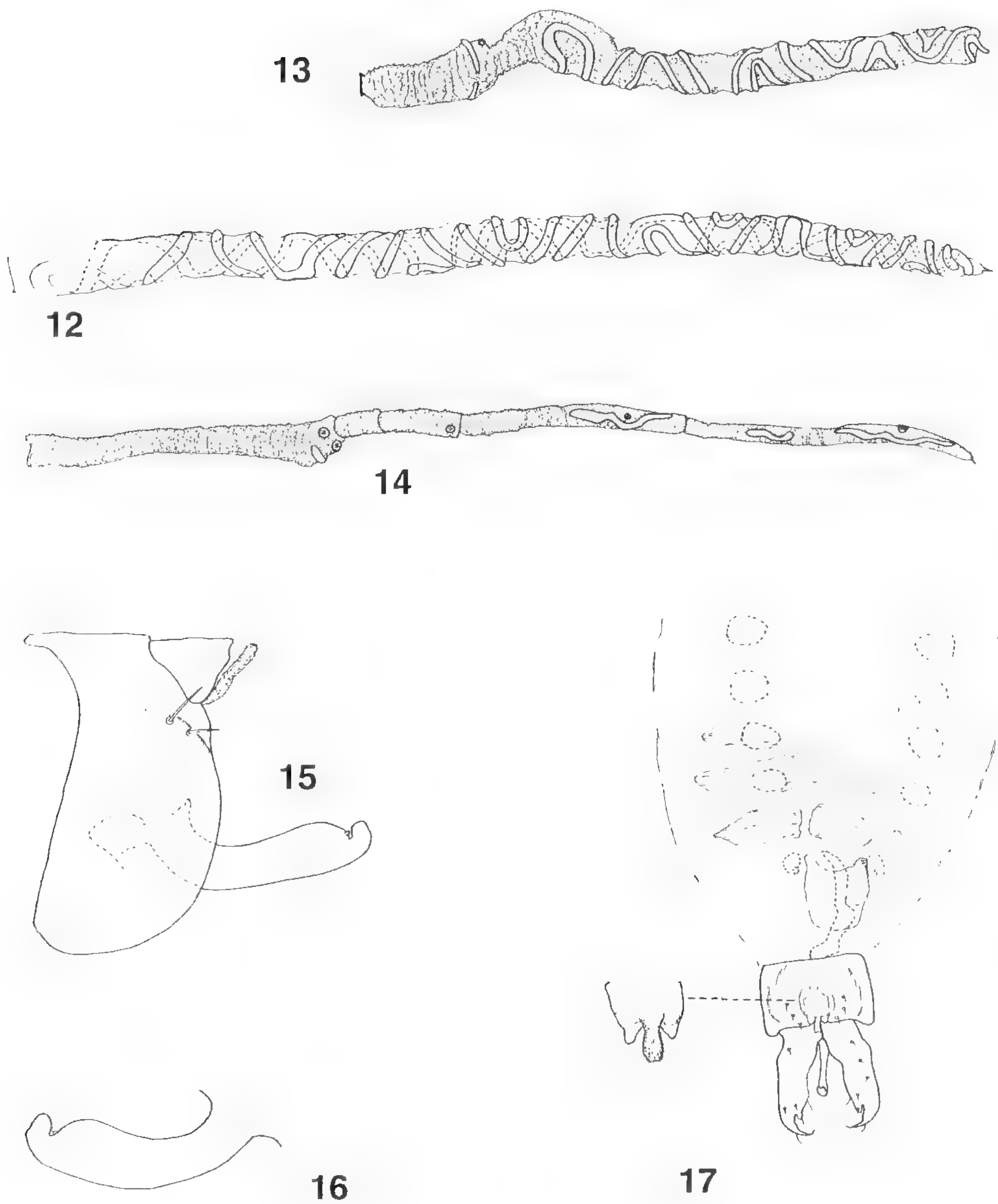
Elongate oval, outline subtly constricted slightly anterior to long meso-metathoracic division (easily mistaken for cephalothoracic-abdominal division but hind legs clearly underlie apparent first abdominal segment), at which point coarse marginal crenulations are somewhat finer in some individuals; third-instar exuvia observed to fold at this meso-metathoracic division; sexual dimorphism apparent, individuals falling into range 1.04-1.09 mm long, 0.49-0.53 mm wide (presumed male) or 1.18-1.27 mm long, 0.56-0.63 mm wide (presumed female), all 2.00-2.13 x as long as wide (n=16); cuticle pale, but with median pigmented patch overlying mouthparts and fore legs, another on abdominal segments I-III, and brownish median pigmentation present between vasiform orifice and abdominal division VII/VIII; anterior and posterior marginal setae present; dorsal chaetotaxy same as in puparia, setae short and blunt or very slightly capitate; abdominal intersegmental divisions II/III to VI/VII pronounced, extending into outer subdorsum; submedian abdominal depressions distinct, thoracic equivalents marked as in puparia; submedian zone rhachisform; submargin with row of geminate pore/porettes; legs typical for third-instar, rather triangular, fore and middle pairs with apical pads directed laterad but hind pair directed posteriorly; antennae vestigial, placed anterior to bases of fore legs.

*Second-instar larva* (Figs 2, 10)

Elongate oval, outline subtly constricted anterior to long meso-metathoracic division, which is only intersegmental division extending into subdorsum; cuticle mostly pale, but with some dusky pigmentation on rhachisform submedian area; size 0.60-0.70 mm x 0.27-0.33 mm (n=34), margin coarsely crenulate; anterior and posterior marginal setae present, large with respect to body size, dorsal chaetotaxy apparently as in puparium and third-instar, but only 2 pairs of thoracic and single pair of submedian 8th abdominal setae distinct in all specimens; other individuals with 6 pairs of subdorsal abdominal and third thoracic pair of setal bases always visible but setae themselves variably, or not, developed; few geminate pore/porette pairs present around periphery of rhachis; legs subtriangular, apical pads distinct; antennae vestigial, anterior to fore legs, lateral to basal (anterior) part of rostral apparatus.

*First-instar larva* (Fig. 11)

Pale, 0.34-0.40 mm x 0.14-0.19 mm (n=16), margin with 16 pairs of finger-like protrusions, smooth between them; each marginal protrusion bearing seta, anterior and posterior-most 3 pairs being long and hair-like; remainder short, slightly capitate; between the anterior-most 2 pairs of protrusion-borne setae is a pair arising from the smooth margin, presumed to be the anterior marginal setae; on this basis, posterior marginal setae absent; as in second and third instars, most pronounced intersegmental division is between meso- and metathorax; dorsum with 4 pairs of cephalothoracic and 7 pairs of abdominal subdorsal capitate setae; ventrally, appendages reflect mobility of this stage, each leg with single articulation between coxa/femur and tibia/tarsus; coxa discernible; tarsus not distinct from tibia but distal segment of leg with apparent single claw-like apex and distinct clubbed subapical digitule; each antenna with 3 distinct segments,




Figs 12-17. *Zaphanera papyrocarpae* Martin sp. nov., adult characters. 12. Male antennal segment III. 13. Male antennal segment IV, with single convoluted sensorium shown. 14. Female antennal segments III-VII. 15. Lateral view of male genital segment. 16. Lateral view of male aedeagus. 17. Dorsal view of male abdomen, with expanded detail of operculum and lingula.

distal one longest and extending posteriorly to base of middle leg; rostral base and ventral abdominal setae fine, at least as long as vasiform orifice.

*Egg* (Fig. 1)

Black, borne at apex of a long pedicel angled such that egg itself almost touches the phyllode surface; laid on to phyllode surfaces, often interspersed with larval stages.

*Adult male* (Figs 12, 13, 15-17)

1.73-1.87 mm long (including parameres), antennae 0.81-0.90 mm, ultimate rostral segment 0.100-0.125 mm (n = 9); wings typical for Aleyrodinae, with main vein of fore and hind wing unbranched, wings unpigmented; abdomen bearing 4 pairs of oval wax glands, about 0.70-0.90 mm long (Fig. 17); parameres, aedeagus, operculum and lingula as illustrated (Figs 15-17); entire abdomen, anterior to genital segment, very finely spinulose, appearing greyish under lower magnification; antennae with only 4 visible segments, segment III usually distinctly angled in its basal third and with single, circular, ciliate sensorium proximad of this "elbow" (Fig. 13); the 2 flagellar segments each with much convoluted, but apparently single, sensorium looping repeatedly around the segment (Figs 12, 13).

*Adult female* (Figs 3, 14)

1.78-1.97 mm long, antennae 0.62-0.75 mm, ultimate rostral segment 0.10-0.13 mm (n = 8); wing characters as in male; abdomen bearing only 2 pairs of oval wax glands, about 0.10 mm long; abdominal surface very finely spinulose, as in male, antennae 7-segmented, IV and V much shorter than remainder of flagellar segments; usually with segment VII bearing 2 sinuous sensoria (the distal one being the longest), segment VI with one sinuous sensorium and segment III with a subapical sensorium of irregular outline but not elongate.

*Etymology*

Named after its host plant, *Acacia papyrocarpa* (Leguminosae: Mimosoideae), the western myall, from which it takes both its specific name and suggested common name, western myall whitefly.

*Taxonomic relationships*

Amongst the four described Australian species of *Zaphanera*, the puparia of *Z. papyrocarpae* sp. nov. appear closest to *Z. niger* (Maskell) and nearly key as such in Martin's (1999) key. *Zaphanera papyrocarpae* shares with *Z. niger* a lack of submedian glandular patches, presence of submedian pairs of abutting abdominal tubercles and exceptionally pronounced intersegmental divisions II/III to VI/VII. The puparia of *Z. papyrocarpae* develop aligned along the narrow, subcylindrical phyllodes of the western myall. It was initially suspected that the new species might be a variant of *Z. niger*, developing greater convexity and a more elongate puparial outline in response to its feeding environment. However, closer examination has indicated several other, consistent, characters that separate these two taxa. The most striking characteristic of the puparia of *Z. papyrocarpae* is the extreme forward-curving of the transverse moulting sutures and abdominal intersegmental divisions II/III to V/VI, a feature not seen in any other examined members of the genus, whether described or not. Puparia of *Z. papyrocarpae* further differ from those of *Z. niger* in only possessing three pairs of cephalothoracic setae of which two pairs are displaced into subdorsum (*Z. niger* has six cephalothoracic pairs, all submarginal), in not possessing a submarginal pair of setae on abdominal segment III (present in *Z. niger*) and in having a short lateral rhachis arm issuing from the outer basal edge of each abdominal anteriorly-directed tubercle (rhachis completely undeveloped in *Z. niger*). Puparia of *Z. niger* have very small, but distinct, submedian abdominal depressions mid way between the intersegmental divisions, whereas the depressions in *Z. papyrocarpae* are difficult to see, given the greater development of the submedian abdominal tubercles. Third-instar larvae of *Z. papyrocarpae* are elongate-oval (more broadly rectangular in *Z. niger*), with characteristic submedian pigmentation (completely pale in *Z. niger*) and elongate submedian abdominal depressions (circular in *Z. niger*) and with a pronounced submedian rhachis (completely absent in *Z. niger*).

To date, the adults of *Z. papyrocarpae* are the only imagos known for any species of *Zaphanera*. Thus, no conclusions can yet be drawn as to whether any of the several unusual adult characters described above are generic or specific. Certainly, the presence of only two pairs of abdominal wax glands in the females is not usual in the Aleyrodinae and the characteristic convoluted antennal sensoria of both sexes are similarly remarkable.

*Life cycle of* Zaphanera papyrocarpae

Western myall whitefly had two distinct generations per year during the study (Fig. 18). An autumn-winter generation commenced with eggs laid in late February and a spring-summer generation started from eggs laid in October. The eggs hatch into mobile first instar larvae that could sometimes be seen dispersing on phyllodes. The sedentary second and third instar larvae (Fig. 2) developed more slowly in winter than in the summer. The fourth instar larvae (= 'pupae') were conspicuous on

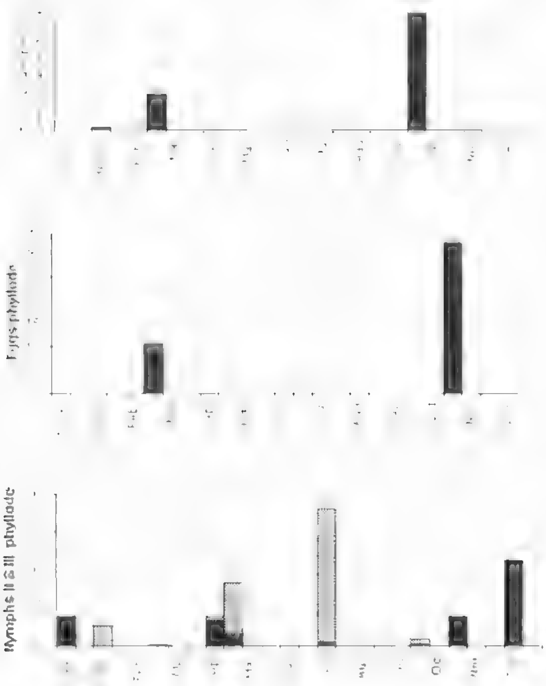



Fig. 18. Generations of *Zaphanera papyrocarpae* Martin sp. nov. Adults emerge from pupae during late summer and spring (top figure) and lay eggs (middle), from which develop the autumn-winter and spring-summer generations of larvae (bottom). Second instar larvae are shown shaded and third instars in black.

phyllodes, where large numbers often appeared to encrust the phyllode (Fig. 4). This stage was closely associated with leaf, shoot and branch death. No honeydew exudate was observed associated with any stage of whitefly development, nor were ants closely associated with whitefly larvae. Adults (Fig. 3) lived for only one or two days when allowed to emerge in the laboratory at 24° C and provided with moisture. The February 2000 sample was taken immediately following rain and the adults were observed flying in small clouds immediately above shoots on trees.

Timing of generations and life history stages can be roughly estimated from Fig. 18. Taking into account the period between egg layings, the autumn-winter generation takes approximately seven months and the spring-summer generation five months. Eggs appear to hatch over a period of no more than four weeks. Duration of the second instar is about 6-8 weeks in March-April and 4-6 weeks in September-November. Duration of the third instar is about 20 weeks in April-September and eight weeks in November-December. Duration of the pupal stage is four weeks in September but up to eight weeks in January-February.

*Demarcation of outbreak*

Trees on which *Z. papyrocarpae* were recorded are contained in an area of approximately 10,000 km north and north-west of Roxby Downs (Fig. 19). Trees showing symptoms of dieback and death associated with western myall whitefly populations were found throughout the area. Outside this area, no evidence of any whitefly species could be found on any *A. papyrocarpa* tree.

Within the area of infestation, mulga trees (*A. aneura*) were sometimes found in close association with western myall, in some cases with touching foliage. These mulga trees were examined but *Z. papyrocarpae* was never recorded. However, another (undescribed) species of *Zaphanera* was occasionally found on them.

*Damage*

Field observations confirmed the association of *Z. papyrocarpae* with dieback and death of trees, first reported by Ireland in 1998 (unpub.). Of several hundred trees examined during the study, those with dieback symptoms were always associated with the presence of western myall whitefly. Symptoms on mature trees included initial yellowing of phyllodes on small areas of the tree, followed by death of foliage on branches (Fig. 5) and then death of woody branches (Fig. 6). Once dead patches appear on mature or young trees, death of the whole tree may occur within one year. As a rough estimate, areas of foliage with an average of 3-5 pupae per phyllode were likely to die.

**_Zarhopaloides anaxenor_** Noyes sp. nov.
(FIGS 20-27)

*Holotype*: ♀, Roxby Downs, South Australia, ex *Zaphanera papyrocarpae*, on *Acacia papyrocarpa* 22.x.1999, J. Zwar (ANIC).

*Paratypes*: South Australia: 6 ♀♀, 10 ♂♂, same data as holotype (ANIC, BMNH, WINC).

*Female*

Length 1.13-1.40 mm (1.40 mm in holotype). Frontovertex pale orange-yellow, paler in ocellar area; face, genae and temples concolorous but slightly paler; occiput black bordered pale orange-yellow; radicle and most of scape concolorous with face, but outer face of scape with broad, dark brown dorsal stripe extending along most of dorsal margin; pedicel with basal two thirds dorsally and laterally dark brown, almost black, ventrally and at apex dusky, pale orange; flagellum testaceous brown, proximal segments darker; anterior half of pronotum black, posterior half translucent pale, yellow or white and clothed in translucent white setae; mesoscutum

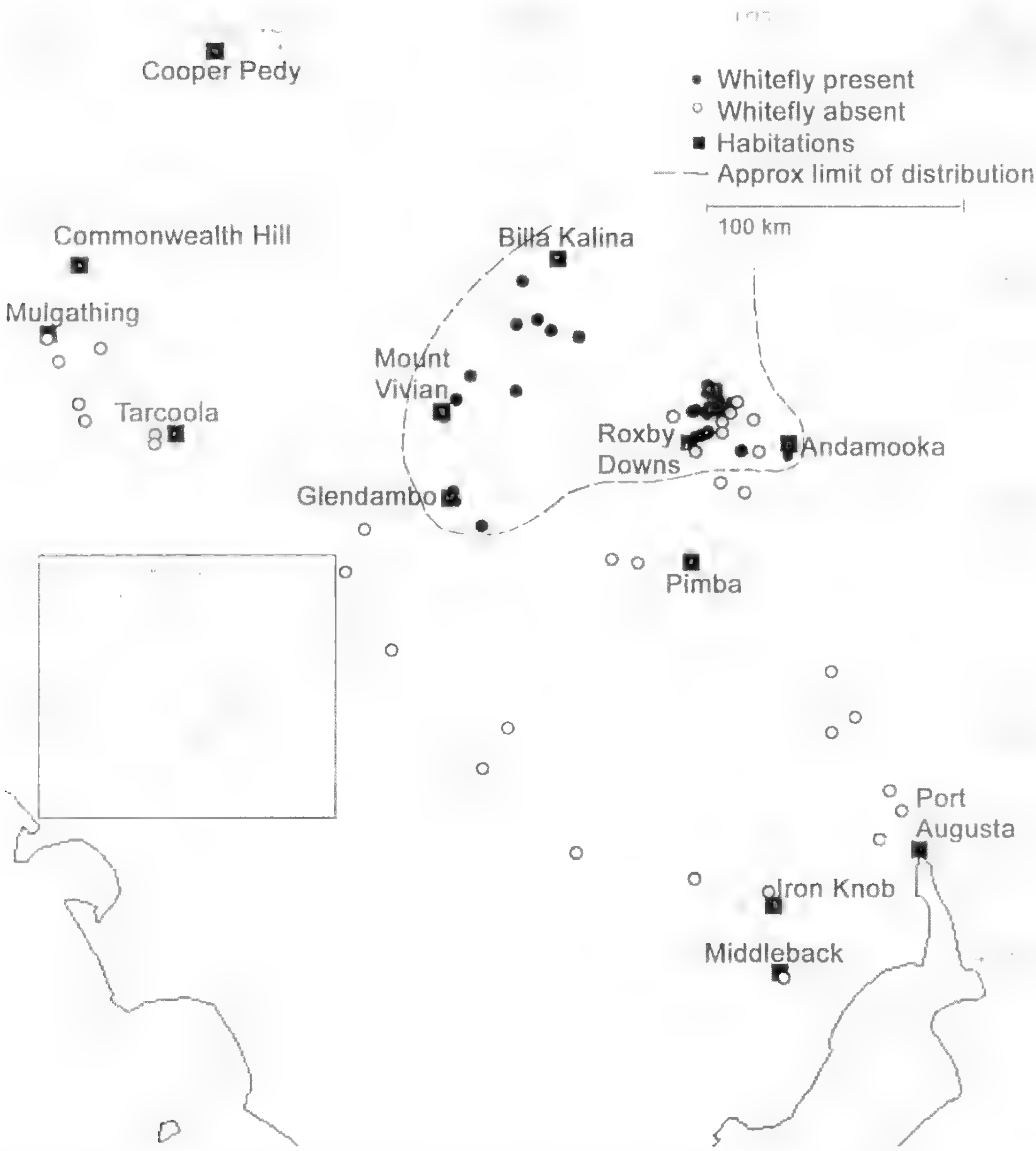



Fig. 19. Surveys of western myall trees on which western myall whitefly, *Zaphanera papyrocarpae* Martin sp. nov., was detected between November, 1999 and July, 2000. The northern edge of the outbreak was not delimited.

shining, metallic blue-green in anterior two-thirds, yellow in posterior one-third and along lateral margins, extreme posterior margin black; axillae yellow; scutellum mostly shining, metallic blue-green mixed, posteriorly purple, apex and lateral margins posteriorly yellow; tegula white with brown apical spot; dorsum of thorax clothed in dense, translucent, white setae; metanotum medially yellow, laterally black; prepectus translucent white, anteriorly dark brown; mesopleuron with small yellow spot below tegula but generally metallic green, bluish posteriorly, slightly purplish dorsally; prosternum metallic green; fore leg with coxa and femur yellow, tibia yellow mixed dusky and margined brown dorsally and ventrally, tarsus pale brown mixed yellow, pretarsus dark brown; mesosternum metallic green; mid coxa metallic green and clothed in conspicuous translucent, white setae, apex yellow, femur yellow, tibia slightly dusky yellow with an inconspicuous brown stripe along most of dorsal margin, tarsus pale yellow with pretarsus dark brown; hind coxa metallic blue-green mixed with purple and clothed with translucent pale brown or whitish setae; hind femur yellow, hind tibia yellow but with narrow brown band at base and two broad, brown bands at one-third and two-thirds its length respectively; tarsus dusky yellow, pretarsus dark brown; wings completely hyaline, venation brown; metapleuron metallic green and clothed in conspicuous translucent white setae; propodeum medially black with slight sheen, greenish towards spiracles, shining blue-green outside spiracle here and clothed in dense, conspicuous, translucent, white setae; gaster dark brown but with strong, metallic blue-green or purplish sheen and clothed in fairly conspicuous, translucent, white setae on basal tergite and laterally; visible part of gonostylus yellow with extreme apex brownish; head about 3.3 x as broad as frontovertex which is about 1.6 x as long as broad and narrowest between anterior ocellus and top of scrobes, ocelli forming an acute angle of about 70°; antenna (Fig. 20) with scape almost cylindrical, a little less than 5 x as long as broad; F1-5 subquadrate, distal segments largest, F6 clearly transverse and largest; clava with apical sensory area distinct giving apex slightly obliquely truncate appearance; linear sensilla on F3-6 and clava; mandibles (Fig. 21) tridentate, upper tooth somewhat truncate; relative measurements: HW=76, FV=23, POL=12.5, OOL=2.5, OCL=7, MS=25; EL=42, EW=39, SL=29, SW=6.5. Visible part of mesoscutum about 2 x as broad as long; scutellum hardly shorter than mesoscutum and slightly broader than long; fore wing about 2.6 x as long as broad; linea calva not interrupted, but closed by one or two lines of setae near posterior wing margin; basal cell densely and evenly pilose; venation as in Fig. 22; relative measurements: FWL=185, FWW=71, HWL=135, HWW=42; gaster about three-fifths as long as thorax; ovipositor as in Fig. 24 exserted part less than one-fifth as long as mid tibial spur; hypopygium (Fig. 23) reaching about half way along gaster; relative measurements (paratype): OL=44, MT=39, GL=8.

*Male*

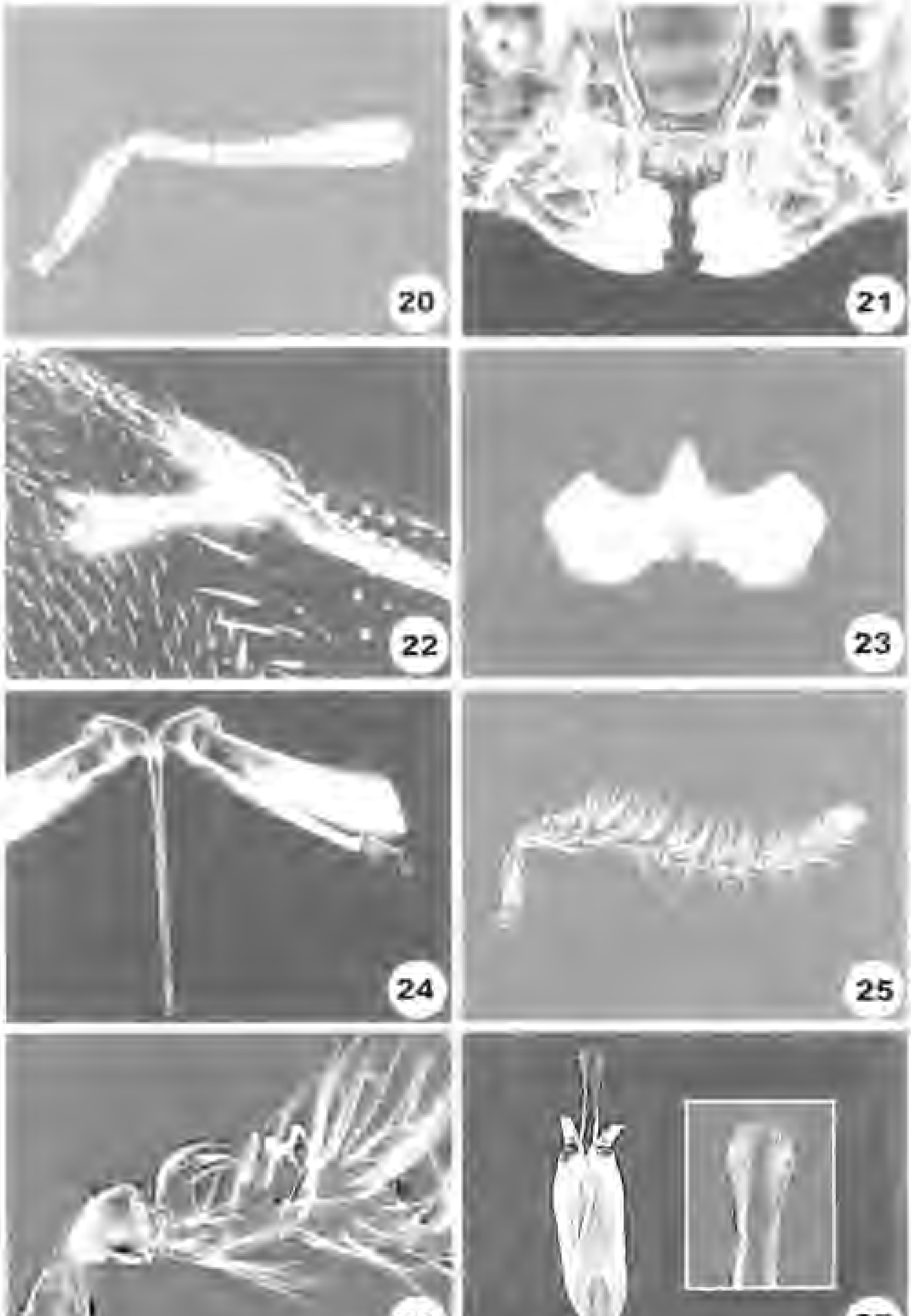
Length 0.98-1.29 mm; very similar to female except for some small differences in colouration, wider frontovertex, antennal structure (Fig. 25), less dense setae in basal cell of fore wing and structure of genitalia; colour as in female but for small, metallic, green spot immediately behind anterior ocellus, flagellum generally yellow with extreme apex of clava brown; mesoscutum, axillae and scutellum completely metallic blue-green; fore tibia with only a small subapical, brown spot on dorsal margin, otherwise fore and mid tibia yellow; hardly marked with brown; head about 2.3 x as broad as frontovertex which is about 1.3 x as long as broad and narrowest about level with anterior margins of posterior ocelli; scrobes broad, subparallel and moderately deep; a small depression between each scrobe dorsally and eye which possibly accommodates F1 in resting position; ocelli forming angle of about 95°, antennal torulus separated from mouth margin by slightly more than 1.5 x its own length with ventral margin a little above lower eye margin; antenna (Fig. 25) with scape short and only about 2 x as long as broad; flagellum clothed in long setae which on proximal segments dorsally are clearly longer than diameter of segments; F1 subquadrate and with deep, dorsal groove giving it a U-shaped appearance (Fig. 26); F2-F6 about 1.5 x as long as broad but giving the rest of the funicle a slightly serrate appearance; clava subcylindrical and a little less than 3 x as long as broad, with apex more or less transversely truncate; relative measurements HW=71, FV=31, POL=19, OOL=3, OCL=7, MS=20, EL=35, EW=30, SL=20, SW=9.5; fore wing about 2 x as long as broad; basal cell with setae conspicuously less dense than in apical half of wing with distinct naked areas near base and below parastigma; relative measurements: FWL=68, FWW=31, HWL=47, HWW=14; aedeagus about half as long as mid tibia, its apex broadly spatulate (Fig. 27); relative measurements: AL=32, MT=70.

*Host*

*Zarhopaloides anaxenor* was reared from *Zaphanera papyrocarpae* Martin sp. nov. (Hemiptera: Aleyrodidae) on *Acacia papyrocarpa*.

*Taxonomic relationships*

*Zarhopaloides* has been characterised by Noyes & Hayat (1984) and Dahms & Gordh (1997) and includes four previously described species. Females of *Z. anaxenor* sp. nov. are most similar to those of *Z. speciosus* Girault in general structure and colouration of the head and dorsum of the thorax. The two species can be distinguished on the distribution of linear sensilla on the funicle and colouration of the hind tibiae and fore wing. In *Z. anaxenor* linear sensilla are present only on F3-F6, the hind tibia has a pair of distinct brown bands and the fore wing is completely hyaline, whereas in *Z. speciosus* all funicle segments possess linear sensilla, the hind tibia is almost completely brown without any distinct bands and the fore wing has a large, subcircular infuscate area below the marginal




Figs 20–27. *Zarhopaloides anaxenor* Noyes sp. nov. 20. Female antenna. 21. Mandibles. 22. Fore wing venation. 23. Female hypopygium. 24. Female ovipositor. 25. Male antenna. 26. First funicle segment, male. 27. Male genitalia (inset - apex of aedeagus).

vein. Females of the other species differ in having the frontovertex and face largely metallic green (*Z. cinctithorax* (Girault)), a subcircular infuscate area below the marginal vein (*Z. aureicaput* (Girault)) or at least F1 strongly transverse and about 2 x as broad as long (*Z. aureicaput* and *Z. axillaris* Girault). Males are known only for *Z. cinctithorax* and have the antennal flagellum filiform with F1 unmodified and clothed in setae which are very much shorter than the diameter of the segments.

There are few authenticated records of Encyrtidae as parasitoids of whiteflies. To date, species of 11 encyrtid genera have been recorded as whitefly parasitoids (Noyes 1998). Most of these are likely to be erroneous observations or one-off 'accidents' where species that normally attack diaspidid scales or other smaller coccoids may attempt to parasitise aleyrodids when their normal hosts are scarce. Other than some undescribed species of *Metaphycus* frequently reared from whiteflies in South America (material in BMNH) and *Rhopus eriantha* (Myartseva) (comb. nov. from *Platyrhopus*) from central Asia, *Z. anaxenor* appears to be the first species to be authenticated as a true parasitoid of aleyrodids.

*Rates of parasitism*

Parasitised pupae were identified by the circular exit hole and predated pupae by a jagged hole. The only parasitoid that emerged from samples of *Z. papyrocarpae* was *Zarhopaloides anaxenor* Noyes sp. nov. The rates of parasitism of pupae of *Z. papyrocarpae* are shown for two periods in Table 1. No parasitoid exit holes were detected in any stage other than the pupa.

TABLE 1. *Apparent mortality of Z. papyrocarpae pupae at Roxby Downs for two sampling periods during 2000*

| Date collected | Total pupae (n) | % parasitism | % predation |
|---|---|---|---|
| 15 Feb. 2000 | 94 | 4 | < 1% |
| 26 Oct. 2000 | 281 | 10 | < 1% |

## Discussion

The outbreak of western myall whitefly and the associated death of many of its host trees is unusual and the cause(s) have not been established with any certainty during this study. A number of possible causes are discussed below.

*Failure of natural enemies*

The parasitoid *Z. anaxenor* was the only natural enemy identified during this study but the biology of this wasp has not yet been studied in detail. The rate of parasitism on western myall whitefly was no greater than 10% during this study and so it is unlikely to have been significant in reducing numbers of this species.

There was no evidence that the outbreak of *Z. papyrocarpae* could be attributed to failure of generalist predators or parasitoids. The presence of predators was inferred from jagged holes in puparia but predation of younger stages of whitefly was unlikely to have been detected because evidence of these stages may fall from the phyllode. Eggs of brown lacewings (*Micromus* spp. - Neuroptera: Hemerobiidae) were frequently observed on sampled phyllodes. Thus, the influence of general predators may have been greater than indicated by these results. However, any failure of these predators should have been in evidence on other species of trees. At a number of sites in the Roxby Downs area, western myall (*A. papyrocarpa*) trees infested with whitefly grow in close proximity to mulga (*A. aneura*), sometimes with overlapping canopies. Careful searching of such mulga trees yielded a different species of whitefly but in very low in numbers. This mulga-associated whitefly was clearly not undergoing any increase in population which might be expected if generalist natural enemies had been absent from the area.

*A new introduction*

This study has not eliminated the possibility that the original plant host of the whitefly was a species of *Acacia* other than *A. papyrocarpa*. Searches of naturally-occurring *Acacia* species in the area of Roxby Downs did not yield any *Z. papyrocarpae* on hosts other than western myall. It is possible that *Acacia* species exotic to the Roxby Downs region may have been introduced and carried the whitefly to the area. This whitefly may then have switched to *Acacia papyrocarpa* but not to any other *Acacia* species in the area. Martin (1999) notes that the related species *Z. niger* has three recorded hosts: *Acacia pycnantha* Bentham, *A. longifolia* (Andrews) Willd. and *A. melanoxylon* R. Br. More data on the host range of *Z. papyrocarpae* need to be collected to test the hypothesis that this whitefly has recently adapted to *A. papyrocarpa*.

*Tree health*

Dying western myall trees were first noticed in the township of Roxby Downs in 1998 (Ireland unpub.). Roxby Downs is a mining town constructed during the past 20 years around existing communities of mature western myall trees. A large copper-uranium mine is located some 20 km from Roxby Downs and, beyond the limits of the mine area itself, there is no evidence of aerial or effluent emissions in the atmosphere or groundwater which might affect tree health.

Some trees within the township had their extensive root systems disturbed by road works and other trees had changed water availability, mainly an increase, resulting from garden irrigation. While the western myall trees in Roxby Downs township live in a disturbed environment, the same is not true of the symptomatic trees up to 100 km distant in the pastoral areas to the north and north-west of the town where land use has changed little during the past 100 years, with sheep, cattle, rabbits and red kangaroos as the main grazing and browsing macrofauna. White (1993) argues that nutritional status of host plants may cause outbreaks of insect populations. In the present case, western myall trees under some form of stress may have provided optimum conditions for the hitherto uncommon *Z. papyrocarpae* to increase its reproductive rate temporarily to outpace its natural enemies. However, the area containing symptomatic trees covers about 10,000 km$^2$, including both recently disturbed township areas and pastoral areas whose land use has remained unchanged for many years. Age of trees does not appear to be a factor, as both younger (1-2 m high) and older trees, up to 6 m high, and at least 160 years old (Lange & Sparrow 1992) or older (Coleman *et al.* 1996), sustain high whitefly numbers and exhibit dieback and death. There have been no discernible changes in rainfall patterns for the past 70 years. Therefore, since conditions for tree growth have remained much the same, there is no evidence to support the suggestion that poor tree health was a contributing factor to the outbreak of western myall whitefly and consequent death of trees.

## Acknowledgments

We wish to thank WMC (Olympic Dam) for their interest and co-operation during this study. In particular, J. Zwar, K. Ashby and J. Read provided encouragement, support and critical comments in equal amounts. Our thanks also to J. Hardy who helped with field and laboratory work, M. Iqbal who assisted with the preparation of digital images and plates, E. Kaesler, who compiled Figure 1 and N. Schellhorn who kindly read the manuscript.

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# DESCRIPTIONS OF TWENTY ONE NEW SPECIES OF CISSEIS (SENSU STRICTO) GORY & LAPORTE 1839 (COLEOPTERA: BUPRESTIDAE: AGRILINAE)

*By S. Barker**

**Summary**

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A redefinition of Cisseis is given and the following twenty one new species of Cisseis (sensu stricto) are described: Cisseis aberrans sp. nov., C. adusta sp. nov., C. armstrongi sp. nov., C. augustgoerlingi sp. nov. C. brooksi sp. nov., C. broomensis sp. nov., C. chalcophora sp. nov., C. corpulenta sp. nov., C. cupreola sp. nov., C. cyanea sp. nov., C. derbyensis sp. nov., C. excelsior sp. nov., C. kohouti sp. nov., C. macmillani sp. nov., C. macqueeni sp. nov., C. pulleni sp. nov., C. septuosa sp. nov., C. speciosa sp. nov., C. stellata sp. nov., C. trimentula sp. nov. and C. watkinsi sp. nov.

Key Words: Australia, Coleoptera, Buprestidae, Cisseis, new species.

*Transactions of the Royal Society of S. Aust.* (2001), **125**(2), 97-113

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Key Words: Australia, Coleoptera, Buprestidae, *Cisseis*, new species.

## Introduction

The genus *Cisseis* Gory & Laporte (1839) is a member of the tribe Agrilini, subfamily Agrilinae. It occurs in Australia, New Guinea and some of the adjacent islands and in the Philippine Islands. The genus was last revised by Carter (1923) and now needs to be re-worked because there has been a large number of new species collected recently. As a first step I examined the available types and designated lectotypes of seven species, elevated a sub-species to full species and described two new species (Barker 1998, 1999a,b). Seven species previously placed in *Cisseis* were recognised as a separate genus and together with nine undescribed species were placed in a new genus *Stanwatkinsius* Barker & Bellamy (2001).

Blackburn (1887, 1891) described some South Australian species of *Cisseis* but missed others through misidentifying *Cisseis notulata* (Germar) (Carter 1923, p. 162). As a consequence, several small species, common in South Australia and known to Blackburn, have remained undescribed. There appear to be changes in the abundance of some species since the earliest collections were made in South Australia, probably because of habitat destruction. Hope (1846) noted that *C. fuscocuprea* "was captured at Moriatta, where it was taken in great abundance". "Moriatta" is probably a misspelling of Morialta, a gorge in the Adelaide foothills now a conservation park. In thirty eight years of collecting in South Australia I have captured one specimen. Kerremans (1890, 1898, 1900, 1903) described thirty nine species, apparently without reference to previous work on the genus as only eighteen are valid.

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Blackburn (1887) proposed the genus *Neospades* which differed from *Cisseis* in having compressed tarsi with the basal metatarsal segment barely longer than the second joint and also in having the tarsal claws stongly divided. Carter (1923) followed Blackburn but later (Carter 1929) relegated *Neospades* to sub-generic status with which I concur.

In future papers I shall describe more new species of *Cisseis* (s.s.), present a key for the identification of all species and a check list.

## Materials and Methods

Specimens examined were borrowed from or are deposited in the following institutions and collections:

AMSA- Australian Museum, Sydney.
ANIC- Australian National Insect Collection, CSIRO, Canberra
BMNH- The Natural History Museum, London.
GNUS- G. Nelson, Blue Springs, MO.
HDWA- H. Demarz, Wanneroo, WA.
HUMB- Humboldt University Museum, Berlin.
JBQA- J. Balderson, Queanbeyan, NSW.
MGBA- M. Golding, Beverley, WA.
MHSA- T. M. S. Hanlon, Sydney, NSW.
MNAG- M. Niehuis, Albersweiler, Germany.
MNHN- Natural History Museum, Paris.
MPWA- M. Powell, Melville, WA.
MSNG- Museo Civico di Storia Naturale, Genoa.
NMVA- Museum of Victoria, Melbourne.
NRSS- Naturhistoriska Riksmuseet, Stockholm.
NMPC- National Museum, Prague.
QMBA- Queensland Museum, Brisbane.
RMBB- Royal Museum, Brussels.
SAMA- South Australian Museum, Adelaide.
SWLA- S. Watkins, Lismore, NSW.
WAMA- Western Australian Museum, Perth.

All of the specimens were examined under a binocular microscope. They were photographed with a Nikon 35 mm camera with extension tubes and the transparencies were scanned and digitally manipulated by computer using Adobe Photoshop. Male genitalia were dissected, mounted on card and also displayed by the method described above.

**Genus** *Cisseis* (s. s.) Gory & Laporte, 1839: 1
*Diphucrania* Dejean, 1833: 81

Type species: *Cisseis stigmata* Gory & Laporte (Bellamy 1998 desig.)

*Diagnosis*

Very small to moderate in length, 3-15 mm; subcylindrical; upper surface transversely rugose; pronotum with two lateral carinae, dorsal one more or less straight and usually reaching apical margin; commonly with prominent pubescent spots or patterns on the dorsal surface; in many species the sexes are dichromatic.

*Description*

Head with eyes 0.4 width, inner margins subparallel; frontovertex breadth:depth ratio 2:1, variably punctured, often with basal impressed line, frequently with median apical sulcus, eyes never deeply divided as in related genera *Ethon* Gory & Laporte, *Alcinus* Deyrolle or *Hypocisseis* Thomson; antennal insertions very large, closely to moderately separated by inter-antennal bridge, with straight to bisinuate carina dorsad to each, epistome declivous ventrad to antennal insertions; gena with acute projection beneath each eye, grooved to receive basal antennomeres; labrum setose; mandible robust. Antennae triangularly serrate from antennomere 4, sometimes compressed. Pronotum width:length ratio 2:1; medially punctate laterally striolate; anterior margin variable from almost straight to strongly projecting medially, basal margin sinuate; laterally prominent dorsal carina, in most species diverging from ventral carina at base, reaching anterior margin; in a few species abruptly ending post-medially surrounded by dense pubescent setae, never approaching ventral carina anteriorly as in coraebine genus *Stanwatkinsius*; space between carinae punctured and often setose. Scutellum scutiform, longer than wide, anterior margin often convex. Elytra scutellate, length:breadth ratio 2:1, sides usually sub-parallel, post-medially rounded, apices rounded and rugose, often sub-serrate, most species with clumps of pubescent setae forming spots or patterns. Ventral surface faintly scutellate, lightly to densely setose; in some species setae clumped laterally to form pubescent white spots on thoracic and abdominal sterna. Legs: tarsal claws bifid and either single or with small inner tooth, in *Cisseis* (*Neospades*) claws are divided; with metatibial setigeris. Genitalia, male, aedeagus often heavily chitinised, in most species parameres have long fine sensory vibrissae at apex without other ornamentation, in a very few species there is an apical brush of dense setae which are folded beneath; one small group has accessory structures of unknown function in the form of lateral paired elongate structures emerging from near base of parameres with terminal brush of setae; female, ovipositor in the form of a flattened tube with paired styli, never as in *Melobasithon* Obenberger (Bellamy 1988) or *Stanwatkinsius* (Barker & Bellamy 2001).

***Cisseis aberrans*** sp. nov.
(FIGS 1A, 2a)

*Holotype*: ♂, Woodridge, W.A., intercept trap, 20.xii.1998, H. Demarz, SAMA I 21 501.

*Allotype*: ♀, Pemberton, 36-801, WAMA.

*Paratypes*: WA: ♀, Perth, H. W. Brown, MHSA; ♀, Denmark, 10.v.1926, W. B. Barnard, QMBA; ♂, Bunbury, i.1942, F. L. Whitlock, ANIC; ♂, Denmark, 20.i.1964, R. P. McMillan, WAMA; ♂, Woodridge, intercept trap, 18.xii.1996, H. Demarz, SAMA; ♂, Woodridge, intercept trap, 7.xii.1998, H. Demarz, HDWA; ♂, Woodridge, intercept trap, 25.i.1999, H. Demarz, HDWA.

*Male*

Size: 5.7 x 2.4 mm (6).

Colour: head, antennae, pronotum, scutellum cupreous. Elytra dark blue with coppery-purple reflections. Ventral surface and legs cupreous. Setae yellow; on elytra in bands forming a yellow and blue pattern.

Shape and sculpture: head with median sulcus, setae at base and apex, inter-antennal bridge 0.25 inter-ocular width. Pronotum striolate, setae laterally and basally, basal fovea extending laterally; apical margin projecting medially; dorsal carina diverging from ventral carina at base converging at middle then more or less parallel, diverging to apical margin but not reaching it. Scutellum scutiform, punctured, extended laterally, anterior margin straight. Elytra scutellate, with the following bands of clumped setae forming the following markings: along base, across middle, across pre-apical area; sub-serrate apically. Ventral surface with moderately long yellow setae clumped at lateral edges of thoracic and abdominal sterna. Legs: tarsal claws with prominent inner tooth.

Aedeagus: heavily chitinised, short and broad towards the apex (Fig. 1A).

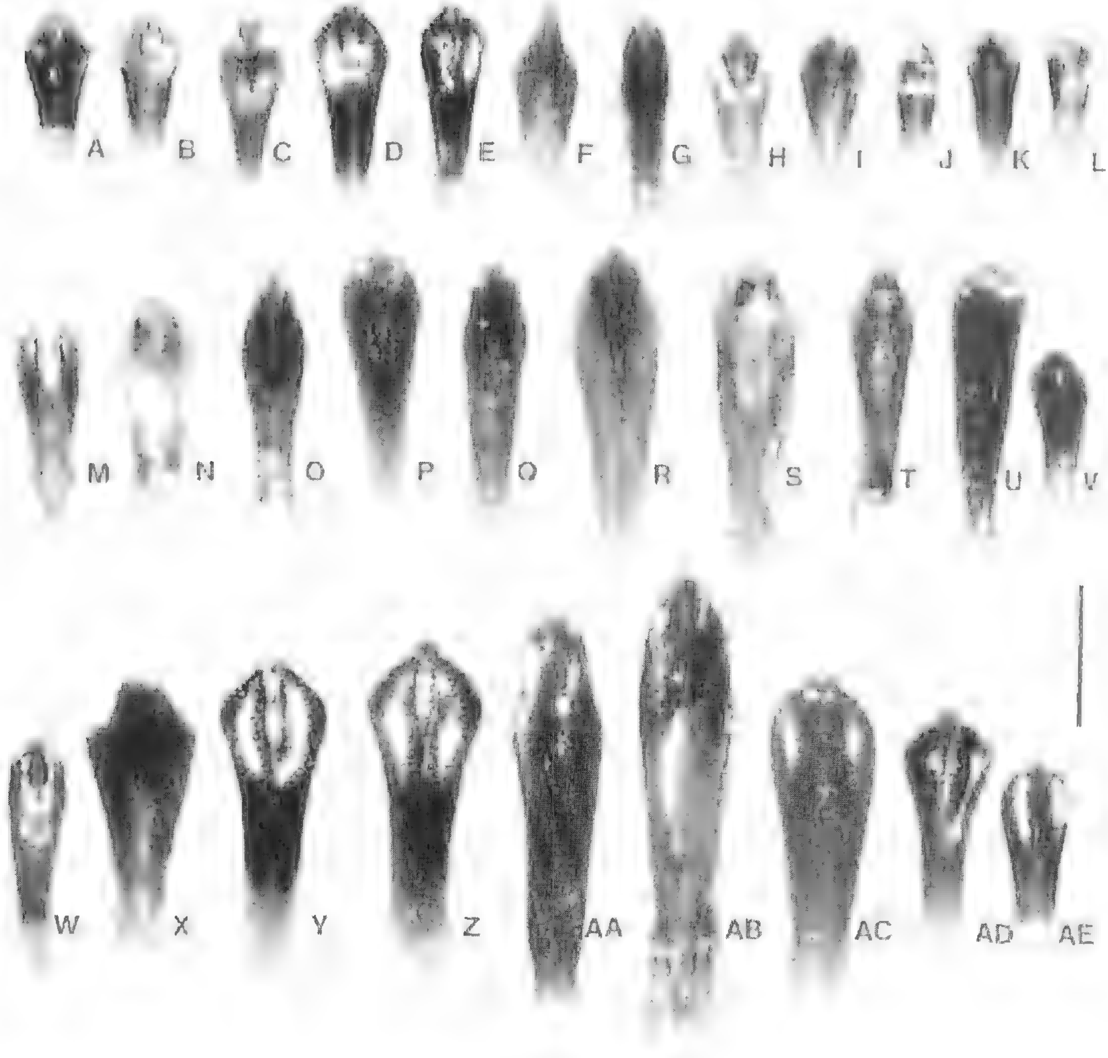


Fig. 1. Photomicrographs of the aedeagi of the following *Cisseis* species: A. *C. aberrans* sp. nov. B. *C. kohoutti* sp. nov. C. *C. macmillani* sp. nov. D. *C. adusta* sp. nov. E. *C. roseocuprea* Hope. F. *C. augustgoerlingi* sp. nov. G. *C. trimentula* sp. nov. H. *C. chalcophera* sp. nov. I. *C. westwoodi* G. & L. J. *C. watkinsi* sp. nov. K. *C. vicina* Kerremans. L. *C. macqueeni* sp. nov. M. *C. pulleni* sp. nov. N. *C. septuosa* sp. nov. O. *C. scabrosula* Kerremans. P. *C. cupreola* sp. nov. Q. *C. prasina* Carter. R. *C. armstrongi* sp. nov. S. *C. corpulenta* sp. nov. T. *C. oblonga* Kerremans. U. *C. cyanea* sp. nov. V. *C. tyrrhena* Carter. W. *C. brooksi* sp. nov. X. *C. broomensis* sp. nov. Y. *C. stellata* sp. nov. Z. *C. signaticollis* (Hope). AA. *C. fulgidicollis* Macleay. AB. *C. derbyensis* sp. nov. AC. *C. opima* Thomson. AD. *C. excelsior* sp. nov. AE. *C. speciosa* sp. nov. Scale bar = 1 mm

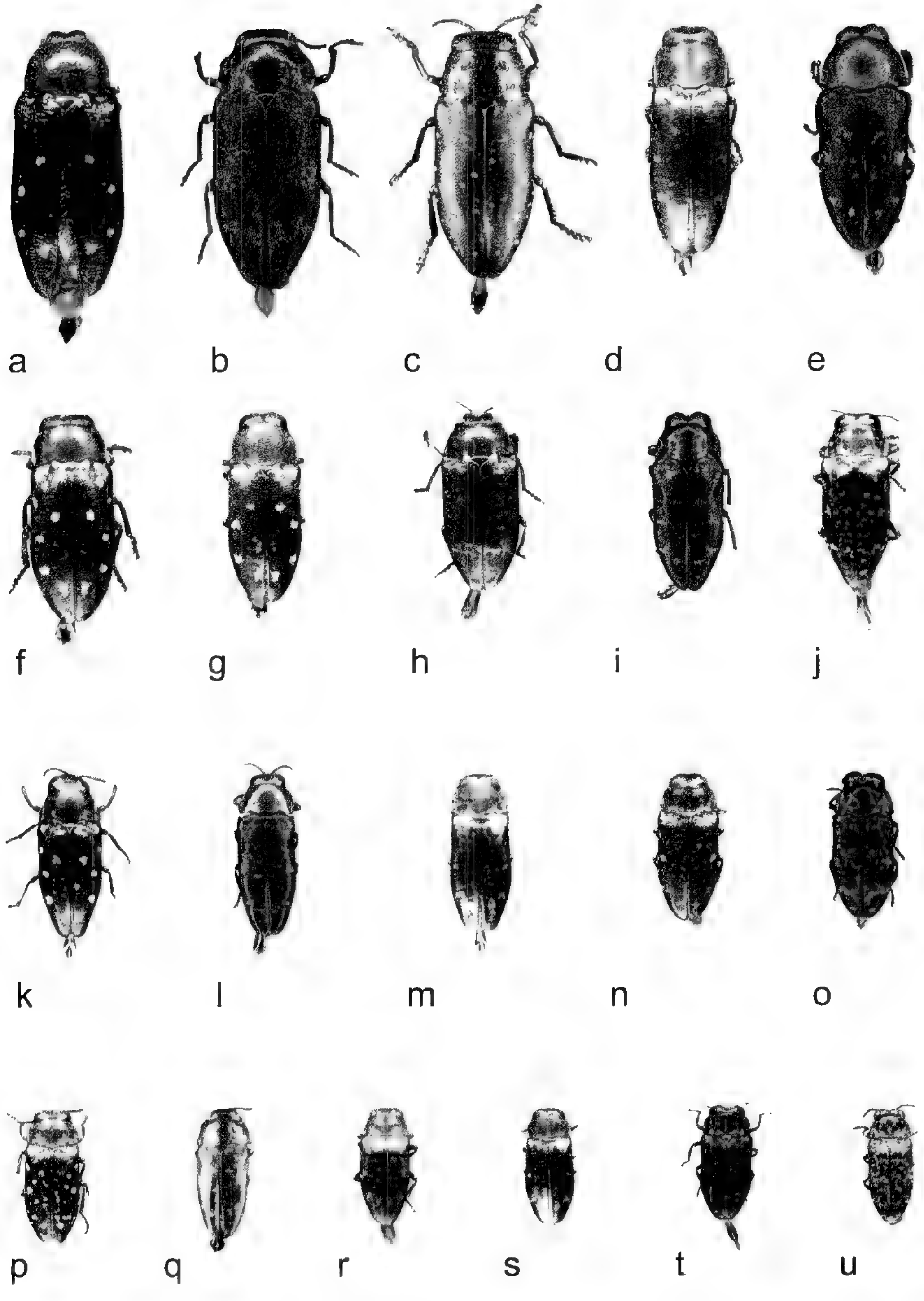


Fig. 2. Habitus illustrations of the following *Cisseis* species: a. *Cisseis stellata* sp. nov. b. *C. macmillani* sp. nov. c. *C. derbyensis* sp. nov. d. *C. armstrongi* sp. nov. e. *C. cupreola* sp. nov. f. *C. broomensis* sp. nov. g. *C. excelsior* sp. nov. h. *C. corpulenta* sp. nov. i. *C. brooksi* sp. nov. j. *C. septuosa* sp. nov. k. *C. augustgoerlingi* sp. nov. l. *C. cyanea* sp. nov. m. *C. chalcophora* sp. nov. n. *C. kohouti* sp. nov. o. *C. aberrans* sp. nov. p. *C. speciosa* sp. nov. q. *C. adusta* sp. nov. r. *C. pulleni* sp. nov. s. *C. macqueeni* sp. nov. t. *C. trimentula* sp. nov. u. *C. watkinsi* sp. nov. Scale bar = 5 mm.

*Female*

Size: 5.8 x 2.4 mm (3).

Colour: as in male.

Shape and sculpture: as in male.

### Remarks

This species is unique in having yellow setae forming patterns on the elytra.

*Etymology*

The species name is derived from *aberrans* L., abnormal.

## *Cisseis adusta* sp. nov.
(FIGS 1D, 2q)

*Holotype*: ♂, Lucindale, S.A., Feuheerdt, SAMA I 21 505

*Allotype*: ♀, same data as holotype, SAMA I 21 506.

*Paratypes*: SA: 2 ♂♂, ♀, Yorks (sic) Penin., Jung, SAMA; ♂ Tintinara, on *Banksia*, N. B. Tindale, 14.ii.1956, SAMA.

*Male*

Size: 5.8 x 2.3 mm (4).

Colour: head mainly green, coppery at base; antennomeres: 1-2 coppery; 3-11 bronze. Pronotum and scutellum brown with coppery reflections; elytra brown with coppery reflections and faint white marks formed from clumped setae. Ventral surface and legs brown with coppery reflections.

Shape and sculpture: head with short impressed line at base projecting into faint median sulcus; inter-antennal bridge 0.15 inter-ocular width. Pronotum striolate, anterior margin projecting medially; dorsal carina sinuate, diverging from ventral carina basally then approaching it just before meeting anterior margin. Scutellum scutiform, flat without punctures, anterior margin straight. Elytra apically sub-serrate, with following faint white marks on each elytron: four in semi-circle from pre-medial to post-medial area, first and fourth closer to suture than margin, second and third closer to margin than suture, with at least one medial at suture. Ventral surface with short setae medially and clumps of long dense setae on lateral coxae and laterally on abdominal sterna. Legs: tarsal claws with small inner tooth.

Aedeagus: heavily chitinised, short and broad towards the apex (Fig. 1D).

*Female*

Size: 5.9 x 2.4 mm (2).

Colour: head mainly coppery, brown at base. Rest as in male.

Shape and sculpture: as in male.

### Remarks

This species could be mistaken for *C. roseocuprea* (Hope) which is the the same size. However, that species does not have elytral markings formed from clumped setae and male genitalia are distinct (Fig. 1E). The only known specimens are old and abraded. Plant associations unknown except that one specimen was collected on *Banksia* sp.

*Etymology*

The species is named for its colour *adustus* L., brown.

## *Cisseis armstrongi* sp. nov.
(FIGS 1R, 2d)

*Holotype*: ♂, Bogan River, N.S.W., taken on *A. pendula*, Myall, J. Armstrong, NMVA.

*Allotype*: ♀, same data as holotype, ANIC.

*Paratypes*: NSW: 2 ♂♂, same data as holotype, NMVA, SAMA; 2 ♂♂, 7 ♀♀, same data as holotype, ANIC, SAMA; 4 ♀♀, Bogan R., J. Armstrong, MHSA.

*Male*

Size: 9.6 x 3.4 mm (5).

Colour: all green; pronotum with yellow reflections. Elytra with white spots formed by clumped pubescent setae.

Shape and sculpture: head flat, inter-antennal bridge 0.2 inter-ocular width. Pronotum striolate; apical margin projecting medially; dorsal carina diverging a short distance from ventral carina at basal margin then gradually converging towards it, not reaching apical margin. Scutellum scutiform, punctured, extending laterally at apex, anterior margin convex. Elytra scutellate, with very short setae pointing posteriorly evenly distributed over whole surface and numerous white spots formed by small clumps of longer pubescent setae; apical margin sub-serrate. Ventral surface with evenly distributed setae projecting posteriorly except at lateral margins of abdominal sterna where they are longer and clumped. Legs: tarsal claws with inner tooth; metatibial setigeris formed from three clumps of setae, the middle one elevated.

Aedeagus: moderately chitinised, elongate (Fig. 1R).

*Female*

Size: 11.3 x 4.0 mm (12).

Colour: all black; head with bronze reflections; pronotum with purple reflections. Elytra with white spots formed from clumped setae.

Shape and sculpture: as in male.

### Remarks

This species is close to *C. prasina* Carter, which has similar coloured males and females, but it is a larger species than *C. prasina* with distinct male genitalia (Fig. 1Q).

*Etymology*

The species is named after the late J. Armstrong of Calubri Station, Nyngan, NSW.

## *Cisseis augustgoerlingi* sp. nov.
(FIGS 1E, 2k)

*Holotype*: ♂, Marloo Stn., Wurarga, W.A., 1931-1941, A. Goerling, ANIC.

*Allotype*: ♀, same data as holotype, ANIC.

*Paratypes*: WA: 21 ♂♂, 19 ♀♀, same data as holotype, ANIC, SAMA; 3 ♀♀, 9km S Pingelly, 2.i.1989, M. Golding, MGBA; 3 ♂♂, 2♀♀, Dedari, 10.i.19, on *Acacia*, H. W. Brown, MHSA.

*Male*

Size: 6.3 x 2.6 mm (25)

Colour: head blue, coppery-purple at base. Pronotum metallic coppery-purple with white pubescent setae. Scutellum coppery-purple. Elytra black with copper-purple reflections and white pubescent setae. Ventral surface and legs coppery-purple. White pubescent setae on lateral margins of abdominal segments.

Shape and sculpture: head flat, inter-antennal bridge 0.2 inter-ocular width. Antennae, compressed. Pronotum faintly striolate medially, deeper laterally, punctured along dorsal margin of dorsal carina; apical margin projecting broadly medially; dorsal carina diverging from ventral carina at base, more or less parallel, diverging just before reaching anterior margin; round fovea on each side near base, filled with pubescent setae. Scutellum scutiform, with faint punctures, expanded laterally near straight anterior margin. Elytra scutellate with single short seta emerging from beneath each plate, projecting posteriorly; 20 white spots formed from clumps of pubescent setae in the following order on each elytron: two along anterior margin, a third beneath humeral callus, one directly posterior to this and another further posteriorly near margin, from middle to near apex four arranged in circular pattern and one medial close to suture; apices finely sub-serrate. Ventral surface medially glabrous but shallowly punctured, laterally scutellate, with clumps of pubescent setae on coxae and abdominal sterna, becoming progressively smaller towards apex. Legs: tarsal claws with minute inner tooth.

Aedeagus: mostly heavily chitinised, broadest post-medially, elongate at apex (Fig. 1F)

*Female*

Size: 7.0 x 2.8 mm (25).

Colour: head coppery-purple. Rest as in male.

Shape and sculpture: as in male, except apex of last visible abdominal sternite heavily spined.

### Remarks

The combination of distribution, colour and shape of the male genitalia make this species unique. In a few specimens the sexual colours are reversed. The plant species with which it is associated is unknown.

*Etymology*

This species is named for the late A. Goerling, of Marloo Station, Wurarga and Pinjarra, Western Australia.

## *Cisseis brooksi* sp. nov.
(FIGS 1W, 2i)

*Holotype*: ♂, Mareeba, i.47, J. G. Brooks, ANIC.

*Allotype*: ♀, Tolga, 7.i.62, Carne, Britton, ANIC.

*Paratypes*: Qld: ♂, ♀, Mareeba, N.Q., xii.52, G. B., SAMA; ♂, 2 ♀♀, Mareeba, xii.58, J. G. Brooks, ANIC; ♀, ANIC; ♂, ♀, Mareeba, 1951, J. G. Brooks, NMPC.

*Male*

Size: 7.4 x 2.8 mm (4).

Colour: head, antennae, pronotum green with yellow reflections. Scutellum bronze. Elytra green-bronze. Ventral surface and legs green with yellow reflections.

Shape and sculpture: head heavily punctured and setose with prominent median sulcus; inter-antennal bridge 0.3 inter-ocular width. Pronotum heavily striolate, laterally setose, with deep basal fovea on each side extending laterally; anterior margin projecting medially; dorsal carina diverging from ventral carina at basal margin, then more or less parallel, diverging to and reaching anterior margin. Scutellum scutiform, with few punctures, laterally extended, anterior margin more or less straight. Elytra heavily scutellate, with the following white spots formed by clumped setae on each elytron: one medial at base; three irregular medial; two irregular post-medial forming a broken fascia; one small pre-apical in middle. Ventral surface scutellate, with moderately long setae and lateral clumps of white setae on thoracic and abdominal sterna. Legs: tarsal claws with small inner tooth.

Aedeagus: moderately chitinised, elongate, broadest towards apex (Fig. 1W).

*Female*

Size: 8.1 x 3.2 mm (6).

Colour: as in male.

Shape and sculpture: as in male.

### Remarks

Two female specimens have a green head with pink reflections. Two specimens in the Prague Museum have an Obenberger manuscript name which I have preserved. This species is distinct from any other because of the colour of the sexes and the medial sulcus on the head.

*Etymology*

The species is named after the late J. G. Brooks, Cairns.

## *Cisseis broomensis* sp. nov.
(FIGS 1X, 2f)

*Holotype*: ♂, Broome, W.A., H. W. Brown, SAMA I 21 509.

*Allotype*: ♀, same data as holotype, SAMA I 21 510.

*Paratypes*: WA: ♂, Hacking gorge, Kimberlies, xii.91, G. Harold, MPWA; 3 ♂♂, 17 ♀♀, same data as holotype, MHSA; ♂, 3 ♀♀, Derby, W.A., H. W. Brown, MHSA; 4 ♂♂, no data, MHSA.

*Male*

Size: 8.3 x 3.2 mm (10).

Colour: Head coppery-red. Antennae black with coppery-red reflections. Pronotum and scutellum coppery-red with green reflections. Elytra black with white spots formed from clumped setae. Ventral surface and legs black with purple reflections.

Shape and sculpture: Head deeply punctured, median sulcus from apex to middle then projecting to base as impressed line; inter-antennal bridge 0.2 inter-ocular width. Antennae compressed, antennules:1-3 obconic; 4-11 toothed. Pronotum striolate, apical margin projecting broadly, basal margin sinuate, dorsal carina diverging from ventral carina basally, then straight and more or less parallel to it until ending abruptly post-medially, space between filled with flattened white setae continuing to apical margin. Scutellum scutiform, extending laterally at concave basal margin, with a few punctures. Elytra scutellate, with single minute seta projecting posteriorly beneath each plate, laterally angled out from margin rounded at humeral callus then more or less parallel-sided until post-medially rounded and narrowed to serrate, round apices, with the following prominent white spots formed from clumped setae on each elytron: largest in middle at base, smaller round spot immediately posterior to it, one close to margin beneath humeral callus, four in semicircle from pre-medial to pre-apical, first and fourth closer to suture than margin, second and third closer to margin than suture, in the middle, one two or three small, faint spots. Ventral surface faintly scutellate with short setae except laterally where they are clumped to form white spots on the meta-coxae and on all abdominal sterna. Legs: tarsal claws with prominent inner tooth; meta-tibial setigeris consisting of three raised clumps from pre-medial to just before distal end.

Aedeagus: mostly heavily chitinised, broadest pre apically, tapered to apex (Fig. 1X).

*Female*

Size: 9.1 x 3.5 mm (21).

Colour: as in male.

Shape and sculpture: as in male

### Remarks

The only other prominently spotted species occurring in the Kimberly district is *C. fulgidicollis* Macleay which has been collected at Derby. It is a larger species than *C. broomensis* sp. nov.; there is a prominent median sulcus on the head; and male genitalia are distinct (Fig. 1AA). There has been only one specimen of this species collected since H. W. Brown made the first collection in November, 1946.

*Etymology*

Named after the type locality.

## *Cisseis chalcophora* sp. nov.
(FIGS 1H, 2m)

*Holotype*: ♂, 3.9 km NW Kapunda, S.Aust., 29.xi.1998, S. Barker SAMA I 21 507.

*Allotype*: ♀, same data as holotype, SAMA I 21 508.

*Paratypes*: SA: ♂, ♀, 2 km NW Kapunda, 12.xii.1986, C. Reid, ANIC; 11 ♂♂, 6 ♀♀, same data as holotype; 5 ♂♂, 4 ♀♀, 3.9 km NW Kapunda, 30.xi.1998, S. Barker SAMA; 4 ♂♂, 2 ♀♀, 3.9 km NW Kapunda, 28.xi.1999, S. Barker, SAMA; ♀, 3.9 km NW Kapunda, 2.xii.2000, S. Barker, SAMA; ♂, Adelaide, no. 647 HUMB.

*Male*

Size: 5.8 x 2.1 mm (23).

Colour: head rose-coppery. Antennae, pronotum, scutellum, sternum and legs coppery. Elytra and abdominal segments yellow-green.

Shape and sculpture: head flat, inter-antennal bridge 0.3 inter-ocular width. Pronotum striolate, anterior margin projecting medially, dorsal carina gradually diverging from ventral carina from basal margin reaching apical margin. Scutellum transverse, flat, without punctures, anterior margin convex. Elytra scutellate with following very faint white spotting on each elytron formed by small clumps of setae; one near margin beneath humeral callus, one medial close to margin, one close to margin in pre-apical area joining one elongate angled closer to suture forming faint, irregular fascia close to suture; apex sub-serrate. Ventral surface: thoracic sterna scutellate; abdominal sterna striolate. Legs: tarsal claws with inner tooth; meta-tibial setigeris from middle to distal end in two prominent clumps.

Aedeagus: moderately chitinised, short, widest pre-apically, tapered to apex (Fig. 1I).

*Female*

Size: 6.3 x 2.2 mm (13)

Colour: all yellow-green.

Shape and sculpture: as in male.

**Remarks**

All specimens collected by me were on flowering *Acacia retinodes* F. Muell. This species of *Cisseis* is close to *C. westwoodi* Gory & Laporte in which both sexes are all green. *Cisseis westwoodi* occurs in NSW, Vic. and Tas. Male genitalia are distinct (Fig. 1I)

*Etymology*

The name, suggested to me by J. McEntee of Erudina Station, refers to the colour of the male head and pronotum *chalkos* Gk. copper.

***Cisseis corpulenta*** sp. nov.
(FIGS 1S, 2h)

*Holotype*: ♂, Tallering Stn., Pindar, W.A., 20.i.1955, S. Barker, SAMA I 21 511.

*Allotype*: ♀, Marloo Stn., Wurarga, W.A., 1931-1941, A. Goerling, ANIC.

*Paratypes*: WA: 5 ♂♂, 2 ♀♀, same data as allotype ANIC; ♂, Pinwanning, 22.i.50, R. P. McMillan, SAMA; ♂ Wialki, 12.xii.1958, R. P. McMillan, WAMA; 2 ♂♂, Mogumber, 12.i.52, R. P. McMillan, SAMA; ♂ Yellowdine, 21.i.1962, A. M. Douglas, L. N. McKenna, WAMA; ♀, Wannamal, 15.xii.1970, S. Barker, SAMA; 2 ♀♀, Wongan Hills, 20.xi.71, H. Demarz, HDWA; ♂, Lake Grace, 29.xii.71, M. Powell, MPWA; 4 ♀♀, Pingrup on *Melaleuca* 13.xii 1973, K. & E. Carnaby, GNUS; ♀, 10 km E Ravensthorpe, 16.xii.1975, S. Barker, SAMA; ♀ Yellowdine, 13.xi.77, M. Powell, MPWA; ♀, Newdegate, 20.xi.77, H. Demarz, HDWA; 2 ♂♂, ♀, 70-75 km ENE Norseman, 10-16.xi.1978, T. F. Houston *et al.*, WAMA; 4 ♂♂, 9.6 km N Marindo, 4 xii.78, M. Powell, MPWA; ♂, 3 ♀♀, Newdegate, 7.xii.80, M. Powell, MPWA; ♂, 20 km N Southern Cross, 30.xii.81, M. Powell, MPWA; ♀, 20 km W Dedari, 12.i.1983, S. Barker, SAMA; 2 ♀♀, 82 km E Hyden, 9.ii.85, M. Powell, MPWA; ♀, 33 km S Borden, 3.i.87, D. Knowles, MPWA; ♀, 14 km E Yellowdine, 11.ii.87, Golding, Powell, MPWA; ♀, Quoin Head, 31.xii.87, Wilson, Knowles, MPWA; ♀, 80 km E Hyden, 8.xii.90, Golding, Powell, MPWA; ♀, 39 km N Koolyanobbing, 17.xi.90, Golding, Powell, MPWA; ♂, 17 km N, Mt Holland, 8.xii.90, Golding, Powell, MPWA; 2 ♂♂, 2 ♀♀, 20 km W Grass Patch, Kershaw, Harold, 24.xi.1996, MPWA; ♂, Three Springs, R. P. McMillan, WAMA; ♀, no data, ANIC

*Male*

Size: 7.8 x 3.3 mm (23).

Colour: head, antennae, pronotum and scutellum bronze. Elytra brown with clumps of setae forming white marks. Ventral surface and legs bronze or coppery-bronze

Shape and sculpture: head with broad median sulcus, inter-antennal bridge 0.2 inter-ocular width. Pronotum shallowly punctured medially, striolate basally and laterally; anterior margin projecting medially; dorsal carina diverging from ventral carina at base more or less parallel to it then converging just before reaching anterior margin. Scutellum scutiform, large, with few punctures, extending laterally at convex anterior margin. Elytra scutellate with very short transparent setae projecting posteriorly and longer white setae forming the following spots on each elytron: basal closer to margin than suture, large pre-medial, large pre-apical, apical, several small irregular in middle along suture; apex sub-serrate. Ventral surface scutellate with short projecting setae, longer on meta-sternal coxae and lateral edges of abdominal sterna. Legs: tarsal claws with small inner tooth.

Aedeagus: moderately chitinised, elongate, widest near apex, penis divided (Fig. 1S).

*Female*

Size: 8.6 x 3.7 (29).

Colour: as in male

Shape and sculpture: as in male.

### Remarks

Mostly collected on the flowers of *Melaleuca* spp. This is a broad species. Male genitalia are very distinct from all but the genitalia of *Cisseis oblonga* Kerremans (Fig. 1T), a very common species in eastern Australia. *Cisseis oblonga* is an elongate species with green head and pronotum and black elytra and is not close to *C. corpulenta* sp. nov.

*Etymology*
This species is named for its broad shape *corpulentus* L., stout.

## *Cisseis cupreola* sp. nov.
(FIGS 1P, 2e)

*Holotype*: ♂, Mt Spec, N.Q., 8.i.65, J. G. B., ANIC.

*Allotype*: ♀, same data as holotype, ANIC.

*Paratypes*: SA: 3 ♂♂, 3 ♀♀, Quorn, Blackburn, SAMA. NSW: 2 ♂♂, Barrington Tops, i.1916, H. J. C., QMBA; ♂, Barrington Tops, i.25, U.S. Zoo. Exp., ANIC; ♂, Blundell Flats, 6.i.1980, D. J. Fergusson, ANIC; 4 ♂♂, Hartley Vale upper Blue Mts, 4.i.1986/29.xii.86/18.i.87, S. Watkins, SAMA; ♂, 2 ♀♀, Armidale, C. F. Deuquet, RMBB. Qld: 3 ♂♂, Mareeba, 19.i.46, S. R. E. Brock, ANIC; ♂, Mt. Spec, 3-7.i.65, J. G. Brooks, ANIC; 4 ♂♂, 4 ♀♀, Mt. Spec, 5.i.65, J. G. B., ANIC; 3 ♂♂, same data as holotype, ANIC; 4 ♂♂, ♀, Mt. Spec, 16.i.65, J. G. B., ANIC; ♂, Rockhampton, xii.64, C. V., ANIC; 3 ♂♂, 2 ♀♀, Ewan Rd, 16-19 km W Paluma, 3-6.i.66, J. G. and J. A. G. Brooks, ANIC; ♂, Blackdown Tableland via Dingo, 1-6.xi.1981, G. Monteith, QMBA; ♂, Blackdown Tableland via Dingo, xi.82, S. Pearson, QMBA; 19 ♂♂, 8 ♀♀, 16 km W Paluma, 10.i.2000, T. M. S. Hanlon, M. Powell, MHSA, MPWA; ♂, ♀, 5 km W Hidden Valley via Paluma, 10.i.2000, T. M. S. Hanlon, M. Powell, MHSA, MPWA; ♂, no data, RMBB.

*Male*
Size: 7.8 x 3.1 mm (55).
Colour: head, antennae, pronotum, scutellum coppery. Elytra black with white markings formed from clumps of pubescent setae. Ventral surface and legs coppery.
Shape and sculpture: head with prominent median sulcus, inter-antennal bridge 0.13 inter-ocular width. Pronotum striolate; apical margin projecting medially; dorsal carina diverging from ventral carina at basal margin, then more or less parallel to it until converging just before meeting anterior margin, with setae along dorsal edge of dorsal carina and in space between the two. Scutellum scutiform, lateral edges extended at convex anterior margin, flat, with few punctures. Elytra scutellate, apex sub-serrate, with following white marks on each elytron: two along base, one in middle of and slightly posterior to above; three in row across middle and one slightly anterior to these and closer to suture than margin, two in pre-apical area, anterior medial, posterior closer to suture than margin. Ventral surface deeply striolate on thoracic sterna, barely on abdominal sterna, with short setae except laterally on meta coxae and abdominal sterna where dense clumps of longer setae form white marks becoming progressively smaller along abdomen. Legs: tarsal claws with small inner tooth.
Aedeagus: heavily chitinised at apex, moderately at base, widest near apex, penis strongly divided at apex (Fig. 1P).

*Female*
Size: 9.0 x 3.6 mm (22).
Colour: as in male.
Shape and sculpture: as in male.

### Remarks

The specimens from Hartley Vale, NSW, were all collected on *Acacia longifolia* (Andr.) Willd. This species has a different colour combination from any other named species.

*Etymology*
The species is named for its colour *cuprum* L., copper.

## *Cisseis cyanea* sp. nov.
(FIGS 1U, 2f)

*Holotype*: ♂, 4.8 km W Wialki, W.A., 21.ix.70, S. Barker, SAMA I 21 512.

*Allotype*: ♀, Northampton, W.A., 16.ix.1958, F. H. Uther Baker, SAMA I 21 513.

*Paratypes*: WA: 3♂♂, 4 ♀♀, Wialki, 5.ix.59, on *Acacia*, S. Barker, SAMA; ♂, same data as allotype, SAMA; ♀, Mingenew, 26.ix.56, F. H. Uther Baker, SAMA; ♂, Strawberry, 27.ix.1956, F. H. Uther Baker, WAMA; ♀, Dandarragan, 29.ix.1956, F. H. Uther Baker, WAMA; ♀, Mingenew, x.56, J. G. Brooks bequest, ANIC; 2 ♂♂, ♀, Wialki, 24.ix.61, F. H. Uther Baker, ANIC; ♀, Irwin, 11.ix.67, F. H. Uther Baker, SAMA; 2 ♂♂, Strawberry, 1.ix.69, F. H. Uther Baker, SAMA; 3 ♀♀, 29 km E Geraldton, F. H. Uther Baker, SAMA; 5 ♂♂, Coral Bay, 29.viii.1974, K. & E. Carnaby, ANIC; ♀, 24 km N Geraldton, 25.viii.1979, T. M. H. Hanlon, WAMA; ♂, Mount Madden, 4.xi.1979, K. & E. Carnaby, ANIC; ♀, Eneabba, 12.ix.1980, R. P. McMillan, WAMA; ♂, 2 ♀♀, 29.12S 115.10E, 23km E by N Dongara, 30.ix.1981, I. D. Naumann, J. C. Cardale, ANIC; ♂, 2 ♀♀, Eneabba, on *Acacia*, 12.vii.1987, R. P. McMillan, WAMA; ♂, 10 km S Eneabba, 20/23.vii.1987, ex flwrs *Acacia*, C. Reid, ANIC; ♂, ♀, Eneabba, from *Acacia* gall, 21.vi.1989, R. P. McMillan, WAMA; ♂, Eneabba, 19.ix.1989, R. P. McMillan, WAMA; ♂, N7T: 32 km E of Yellowdine, 21.x.1991, T. M. S. Hanlon, MHSA; 2 ♀♀, Eneabba, 29°49' S 115°16' E, 5.ix.1996, R. P. McMillan, WAMA; ♂, 2 ♀♀, 53 km W Mullewa, 20.ix.1996, T. M. S. Hanlon, MHSA; 4 ♂♂, ♀, Tammin, H. W. Brown, WAMA; 3 ♂♂, 4 ♀♀ Borden, H. W. Brown, MHSA; 5 ♂♂, ♀, Tammin, H. W. Brown, MHSA; 5 ♂♂, ♀, Eradu, H. W. Brown, MHSA.

Male

Size: 6.5 x 2.4 mm (39).

Colour: head, antennae, pronotum and scutellum bronze. Elytra either violet-blue or cupreous. Ventral surface and legs, bronze, green-bronze or cupreous.

Shape and sculpture: head with median impressed line; inter-antennal bridge 0.2 inter-ocular width. Pronotum striolate, anterior margin more or less straight, basal margin sinuate, dorsal carina diverging from ventral carina at basal margin, then more or less parallel and reaching anterior margin. Scutellum scutiform, punctured, extended laterally, anterior margin convex. Elytra scutellate with the following patches of white setae on each elytron: one medial at base, one medial near margin, wavy pre-apical fascia from margin to suture and small irregular clumps close to suture; apex sub-serrate. Ventral surface heavily scutellate on thoracic sterna, faintly on abdominal sterna, covered with very short setae. Legs: tarsal claws single.

Aedeagus: heavily chitinised, parameres more or less parallel-sided for the whole of their length and indented at the base (Fig. 1U).

*Female*

Size: 7.1 x 2.6 mm (32).

Colour: as in male.

Shape and sculpture: as in male.

## Remarks

The elytral colour is not sex associated. Most of those with cupreous elytra have a cupreous ventral surface. Those with cyaneous elytra never have a cupreous ventral surface. At Eneabba the larvae of this species form galls on *Acacia blakelyi* Maiden (R. P. McMillan pers. comm. 1999). This species has previously been misidentified as *C. tyrrhena* Carter, a broader species with very different male genitalia (Fig. 1V).

*Etymology*

The species is named for the elytral colour *kyaneos* Gk, dark blue.

## *Cisseis derbyensis* sp. nov.
(FIGS 1AB, 2e)

*Holotype*: ♂, Derby, N.W.A., on broad-leafed *Acacia*, 12.ii.1947, H. W. Brown, SAMA I 21 519.

*Allotype*: ♀, same data as holotype, SAMA I 21 520.

*Paratypes*: W.A.: 4 ♀♀, same data as holotype, WAMA; 3 ♂♂, 3 ♀♀, same data as holotype, MHSA; 4 ♀♀, Derby N.W.A., on broad-leafed *Acacia*, H. W. Brown, MHSA.

*Male*

Size: 10.5 x 4.2 mm (4).

Colour: Head, antennae, pronotum and scutellum green with yellow reflections. Elytra dark coppery-red with faint white spots formed from clumps of setae. Ventral surface and legs green.

Shape and sculpture: Head deeply punctate, with a faint impressed line from middle to base, inter-antennal bridge 0.15 inter-ocular width. Antennae normal, antennules: 1-3 obconic; 4-11 toothed. Pronotum punctate medially, striolate laterally, with two poorly defined fovea on each side the anterior smaller than the posterior, anterior margin projecting medially, basal margin sinuate, dorsal carina diverging from ventral carina then more or less straight and gradually diverging from ventral carina reaching anterior margin. Scutellum scutiform, with few punctures, sides extended laterally at basal margin. Elytra scutellate, laterally angled outwards from base then rounded at humeral callus, more or less parallel-sided until rounded post-medially and narrowed to sub-serrate, rounded apex, with the following white marks on each elytron formed from clumps of setae: laterally four small spots, pre- and post-medial, sub-apical and apical and a number of much smaller fainter spots evenly distributed over elytra. Ventrally faintly scutellate with few medial setae but with patches of long lateral setae on each of the abdominal sterna. Legs: tarsal claws with inner tooth; metatibial setigeris from middle to before distal end in four raised clumps.

Aedeagus: heavily chitinised at apex, moderately at base, elongate, widest post-medially, tapered in two steps to apex, apical sensilli very prominent (Fig. 1AB).

*Female*

Size: 11.5 x 4.4 mm (12).

Colour: entirely dark coppery-red.

Shape and sculpture: as in males.

### Remarks

This species can only be confused with *C. fulgidicollis* which occurs in the same area. They can be separated by the following: *C. fulgidicollis* has larger and more prominent elytral spotting; *C. fulgidicollis* has a median sulcus on the head, whereas the head in *C. derbyensis* is flat; the male genitalia differ (Fig. 1AA). All known specimens were collected at the same time by H. W. Brown

*Etymology*
The species is named after its type locality.

## *Cisseis excelsior* sp. nov.
(FIGS 1AD, 2g)

*Holotype*: ♂, 43 km N of Mt Carbine, Qld, 12.i.2000, on *Euhoulea* leaves, T. M. S. Hanlon, M Powell, SAMA I 21 514.

*Allotype*: ♀, same data as holotype, SAMA I 21 515.

*Paratypes*: 4 ♂♂, 10 ♀♀, same data as holotype, MHSA, MPWA, SAMA.

*Male*
Size: 8.1 x 3.1 mm (5).
Colour: head coppery-purple, antennomeres 1-2 coppery-purple; 3-11 black with coppery-purple reflections. Pronotum and scutellum coppery-bronze or green-bronze. Elytra black with white marks formed from clumps of setae. Ventral surface and legs coppery-bronze.
Shape and sculpture: head with median fovea; inter-antennal bridge 0.2 inter-ocular width. Pronotum heavily striolate, anterior margin projecting medially; dorsal carina not meeting ventral carina at base, more or less straight and diverging from it, not reaching anterior margin. Scutellum scutiform, punctured, laterally extended at base, anterior margin straight. Elytra scutellate, with following white marks on each elytron formed from clumps of flattened setae: one medial at base, four in semi-circle around pre- and post-medial areas and two or three medial close to suture. Ventral surface scutellate with short setae, except laterally on meso-coxae, meta-coxae and abdominal sterna where they are longer, clumped and pubescent. Legs: tarsal claws with small inner tooth.
Aedeagus: heavily chitinised at apex, moderately at base, widest near apex, penis divided apically (Fig. 1AD).

*Female*
Size: 9.1 x 3.4 mm (11)
Colour: head, pronotum and scutellum coppery-bronze or green-bronze. Elytra as in male. Ventral surface and legs bronze.
Shape and sculpture: as in male

### Remarks

This is a very distinct species, difficult to confuse with any other.

*Etymology*
The species is named for its distinctness from other species *excelsior* L., higher

## *Cisseis kohouti* sp. nov.
(FIGS 1B, 2n)

*Holotype*: ♂, Uriara Rd, 11km WSW Canberra, 23.xii.1973, K. R. Pullen, ANIC.

*Allotype*: ♀, same data as holotype, ANIC.

*Paratypes*: ACT: 2 ♂♂, 2 ♀♀, 35.16S 149.07E, 590m, Botanic Gardens, Black Mntn, A.C.T. 11.i.1972, R. J. Kohout, QMBA; 4 ♂♂, same data as holotype, ANIC, SAMA, Qld: 2 ♀♀, Stanthorpe, E Sutton, QMBA, NSW: 2 ♂♂, Nowra, 12/52, R. D., J. G. Brooks bequest, ANIC.

*Male*
Size: 5.9 x 2.3 mm (9).
Colour: head green apically, black basally. Antennomeres: 1-2 green; 3-11 bronze. Pronotum green. Scutellum green. Elytra black with white marks formed from clumps of setae. Ventral surface and legs green with yellow reflections.
Shape and sculpture: head with median impressed line at base projecting into median sulcus, narrow and deep near apex; inter-antennal bridge 0.15 inter-ocular width. Pronotum striolate, anterior margin projecting medially, large shallow fovea near each basal angle, dorsal carina diverging from ventral carina basally, widely separated but more or less parallel sided to it, meeting anterior margin. Scutellum scutiform, punctured, sides expanded laterally near straight anterior margin. Elytra scutellate, sub-serrate apical margin, each elytron with following white marks: one at base closer to margin than suture, one beneath humeral callus, four in semi-circle around pre and post-medial area, first and fourth closer to suture than margin, second and third closer to margin than suture, three or four smaller marks inside along suture. Ventral surface scutellate with short setae medially and longer clumped setae laterally on meta-coxae and abdominal sterna. Legs: tarsal claws with prominent inner tooth.
Aedeagus: moderately chitinised, short, widest pre-apically, tapered to apex (Fig. 1B).

*Female*

Size: 6.1 x 2.4 mm (5).

Colour: head coppery apically, black basally. Antennomeres bronze. Pronotum black. Scutellum bronze or coppery. Elytra black with white marks formed from clumps of setae. Ventral surface and legs black with green-blue reflections.

Shape and sculpture: as in male.

### Remarks

Males of this species have a similar colour combination to males of *C. oblonga* Kerremans, but are smaller and have different shaped male genitalia (Fig. 1B).

*Etymology*

The species is named after R. J. Kohout, Brisbane.

### *Cisseis macmillani* sp. nov. (FIGS 1C, 2b)

*Holotype*: ♂, Wanneroo, W.A., on *Xanthorrhea*, 10.iii.1949, R. P. McMillan, SAMA I 21 516.

*Allotype*: ♀, same data as holotype, SAMA I 21 517.

*Paratypes*: WA: ♂, same data as holotype, SAMA; 2 ♀♀, Wanneroo, on *B. attenuata*, 10.iii.1949, R. P. McMillan, SAMA; ♂, 8 km W Mt Barker, 28.ii.56, J. A. L. Watson, SAMA; ♀, Darlington, J. Clark, SAMA.

*Male*

Size: 8.2 x 3.4 mm (3).

Colour: head and antennae coppery. Pronotum and scutellum bronze. Elytra brown with white markings formed from clumps of setae. Ventral surface and legs bronze.

Shape and sculpture: head with very small irregular median sulcus at apex; inter-antennal bridge 0.2 inter-ocular width. Pronotum punctate medially, striolate laterally; apical margin projecting medially; dorsal carina diverging from ventral carina at basal margin then more or less parallel until diverging as it approaches apical margin which it meets; setae present dorsal to dorsal carina. Scutellum scutiform, with few punctures, extended laterally, anterior margin convex. Elytra scutellate, sub-serrate apically, with following clumps of white setae on each elytron forming an irregular pattern: one at base, one near margin posterior to humeral callus; one irregular medial, pre-apical fascia with short side angled anteriorly from margin and longer side angled posteriorly reaching suture. Ventral surface scutellate except for smooth edges of abdominal sterna, with moderately long single setae scattered over whole surface, adpressed and pointing posteriorly except along lateral edges where they are slightly clumped. Legs: tarsal claws without inner tooth.

Aedeagus: moderately chitinised, short, widest post-medially, tapered to apex (Fig. 1C).

*Female*

Size: 10.7 x 4.4 mm (4).

Colour: head, antennae, pronotum, scutellum, ventral surface and legs bronze. Elytra brown with white markings.

Shape and sculpture: as in male.

### Remarks

This species could only be confused with *C. opima* Thomson, which has a spotted elytral pattern and heavily chitinised aedeagus; *C. macmillani* has an obscure elytral pattern and lightly chitinised aedeagus of different shape (Fig. 1AC). The specimens examined from Wanneroo were collected on *Banksia attenuata* R. Br. and *Xanthorrhea* spp.

*Etymology*

The species is named after R. P. McMillan, Kallaroo.

### *Cisseis macqueeni* sp. nov. (FIGS 1L, 2s)

*Holotype*: ♂, Milmerran, Qld, 28.xi.1943, J. McQueen, ANIC.

*Allotype*: ♀, same data as holotype, ANIC.

*Paratypes*: 2 ♂♂, 5 ♀♀, same data as holotype, ANIC & SAMA; 5 ♀♀, Milmerran, xii.1943, J. McQueen, ANIC.

*Male*

Size: 4.7 x 1.7 mm (3).

Colour: head and antennae green. Pronotum and scutellum bronze-green. Elytra black with bronze reflections along suture from base to middle and irregular white spots. Ventral surface black. Legs black with bronze-green reflections.

Shape and sculpture: head with faint medial impressed line; inter-antennal bridge 0.3 inter-ocular width. Pronotum striolate, anterior margin projecting medially, shallow basal fovea on each side from middle to dorsal carina with moderately long white setae; dorsal carina diverging from ventral carina at base, then more or less parallel, reaching anterior margin. Scutellum scutiform, expanded laterally, punctured, anterior margin convex. Elytra scutellate, apical margin subserrate, with white setae forming following faint pattern on each elytron: small medial spot at anterior margin, medial spot at margin and one near suture with larger spot just anterior to it and two or three smaller spots at margin posteriad; short fascia from pre-apical margin slightly anterior to pre-apical spot near suture. Ventral surface faintly scutellate with fine very short setae and clumps of white pubescent setae on lateral meta-coxae and abdominal sterna. Legs: tarsal claws with short inner tooth.

Aedeagus: moderately chitinised, short, widest pre apically, tapered to apex (Fig. 1L).

*Female*

Size: 4.9 x 1.7 mm (11).

Colour: head and antennae coppery. Pronotum and scutellum bronze. Elytra black with bronze reflections along suture from base to middle and irregular white spots. Ventral surface black. Legs black with bronze reflections.

Shape and sculpture: as in male.

**Remarks**

This species is closest to *C. vicina* Kerremans. However it is smaller, the male has only a green head, whereas the male of *C. vicina* has a green head and pronotum and male genitalia are different (Fig. 1K).

*Etymology*

The species is named after the late J. Macqueen, Milmerran and Toowoomba.

***Cisseis pulleni*** sp. nov.
(FIGS 1M, 2r)

*Holotype*: ♂, 10 km NW Edungalba, Qld, Ti-tree creek on Yellow wood, 1.xi.1975, S. Barker, SAMA I 21 518.

*Allotype*: ♀, Black Mountain, 13.xii.1968, on *Acacia* spp., K. Pullen, ANIC.

*Paratypes*: ACT: 4 ♂♂, ♀, same data as allotype, ANIC, SAMA. Queensland: 7 ♂♂, i.41, Milmerran, J. Macqueen, ANIC; 3 ♂♂, 3 ♀♀, Milmerran, xii.43/i.44, J. Macqueen, ANIC; 2 ♂♂, ♀, i.44, J. MacQueen, NMVA; ♂, Milmerran, 4.xii.1943, J. Macqueen, ANIC; 6 ♂♂, 3 ♀♀, Milmerran, xii.43/i.44/ii.44, J. Macqueen, ANIC; 3 ♂♂, ♀, i.44, Milmerran, J. Macqueen, ANIC; 6 ♂♂, ♀, Mourangee, Edungalba, on brigelow, 18.xii.1947, E. E. Adams, ANIC; ♀, Milmerran, iii.1951, J. Macqueen, ANIC; ♂, ♀, Gayndah, xi.56, E. Smith, NMVA; ♂, 16.19S 145.24E 12 km SE of Daintree, J. Balderson, 22.xi.1981, ANIC; ♀, no data, S. R. Brock, SAMA.

*Male*

Size: 4.8 x 2.1 mm (34).

Colour: head mostly green, coppery at base. Antennae green. Pronotum coppery-bronze. Scutellum bronze. Elytra bronze basally, black medially, coppery apically. Ventral surface coppery. Legs: 1, dorsal surface of femur and tibia green, rest coppery; 2, 3 all coppery.

Shape and sculpture: head striolate basally, median apical sulcus, apical edge of frons concave, inter-antennal bridge 0.25 inter-ocular width. Pronotum striolate, with few setae, anterior margin projecting medially; dorsal carina diverging from ventral carina from basal margin reaching anterior margin, space between punctured. Scutellum scutiform, closely punctured, basal margin convex. Elytra striolate basally, elsewhere scutellate, with following obscure marks on each elytron formed from clumped setae: in middle closer to margin than suture, two pre-apical, one closer to margin than suture the other ventrad to it and closer to suture than margin. Ventral surface striolate, faintly on abdominal sterna, with very short, spaced setae. Legs: tarsal claws with inner tooth.

Aedeagus: lightly chitinised, moderately elongate, widest pre-apically with a long, rounded, pre-apical setal brush on each paramere (Fig. 1M).

*Female*

Size: 6.0 x 2.6 mm (14).

Colour; head, antennae, pronotum and scutellum bronze. Elytra bronze basally, black medially, coppery apically. Ventral surface and legs coppery.

Shape and sculpture: as in male.

**Remarks**

This species superficially resembles *C. scabrosula* Kerremans. However, it is smaller and the male genitalia clearly distinguish it from the other species in which the male genitalia have no accessory structures (Fig. 1O).

*Etymology*

The species is named after K. Pullen, Canberra.

***Cisseis septuosa*** sp. nov.
(FIGS 1N, 2t)

*Holotype*: ♂, Charity Ck Bridge via Mount George Manning River N.S.W., 7.xi.91, S. Watkins, SAMA I 21 521.

*Allotype*: ♀, same data as holotype, SAMA I 21 522.

*Paratypes*: NSW: ♂, Lapstone Hill lower Blue Mts, 14.xi.1983, S. Watkins, ANIC; ♂ Stockyard home

Combined Street Wingham, 23.xii.1990, S. Watkins, SAMA; ♂, Charity Creek via Kimbricki Manning River, 11.x.1991, S. Watkins, SAMA; 2 ♂♂, ♀, Charity Ck Bridge via Mount George Manning River, 29.x.1991, on *Casuarina cunninghamiana*, S. Watkins, SAMA; ♂, 2 ♀♀, Charity Ck Bridge via Mount George Manning River, 4.xi.91, S. Watkins, ANIC; ♂, same data as holotype, ANIC; ♀, Charity Creek via Kimbricki Manning River, 14.xi.1991, on *Casuarina cunninghamiana*, S. Watkins, SAMA; ♀, Charity Ck Bridge via Mount George Manning River, 18.xi.91, S. Watkins, ANIC; 2 ♂♂, Charity Ck Bridge via Mount George Manning River, 31.i./30.x.92, on *Casuarina cunninghamiana*, S. Watkins, ANIC;♀, Manning River at Tinonee Rd. via Wingham, 9.xii.1995, *Tristaniopsis*, S. Watkins, ANIC. Qld: ♂, Herberton, xii.52, G. B., ANIC; ♂, N. Qld, Blackburn collection, SAMA. SA: ♂, Summit Mt Barker, 16.xii.67, on *Casuarina stricta*, S. Barker, SAMA.

*Male*

Size: 6.9 x 2.6 mm (13).

Colour: head green. Antennomeres: 1 yellow-green; 2-11 dark brown with yellow reflections. Pronotum and scutellum yellow-green. Elytra black with obscure white marks formed from clumps of setae. Ventral surface, sternum, fused abdominal segments and legs yellow-green; free abdominal segments bronze.

Shape and sculpture: head with deep median sulcus, inter-antennal bridge 0.2 inter-ocular width. Pronotum striolate, anterior margin broadly projecting medially, with shallow basal fovea on each side, dorsal carina diverging from ventral carina at base, more or less straight until reaching anterior margin. Scutellum scutiform, punctured, laterally extended at straight anterior margin. Elytra scutellate, apical margin sub-serrate, with following faint white marks on each elytron: variable number of small spots along surface, irregular fascia post-medial from margin to suture and round pre-apical spot. Ventral surface scutellate with short setae except laterally on metacoxae and abdominal sterna where clumps of longer setae form white spots. Legs: tarsal claws with small inner tooth.

Aedeagus: lightly chitinised, short, widest pre-apically rounded to apex, penis divided apically and strongly pointed (Fig. 1N).

*Female*

Size: 8.0 x 3.0 mm (7).

Colour: head, antennae, pronotum and scutellum bronze. Elytra as in male. Ventral surface and legs black with bronze reflections.

Shape and sculpture: as in male.

**Remarks**

The males of this species have similar colouration to males of *C. scabrosula* Kerremans. It is a larger species than *C. scabrosula* and male genitalia are distinct (Fig. 1O).

*Etymology*

The species name is derived from *septuosus* L., obscure.

***Cisseis speciosa*** sp. nov.
(FIGS 1AE, 2p)

*Holotype*: ♂, Midland Junction, W.A., xii.37, R. P. McMillan, SAMA I 21 523.

*Paratypes*: WA: ♂, Cannington, W.A., 5.xi.56, R. P. McMillan, WAMA; ♂, Bayswater, 17.i.47, R. P. McMillan, WAMA.

*Male*

Size: 5.7 x 2.2 mm (3).

Colour: head green with yellow reflections, antennae bronze. Pronotum, scutellum green with yellow reflections. Elytra black with white spots formed by clumped setae. Ventral surface and legs dark green.

Shape and sculpture: head with shallow median sulcus at apex, inter-antennal bridge 0.2 inter-ocular width. Antennomeres: 1-3 obconic; 4-11 triangular. Pronotum striolate; anterior margin projecting medially, dorsal carina diverging from ventral carina at basal margin continuing to diverge slightly but not reaching anterior margin. Scutellum scutellate, sides extending laterally at convex anterior margin, punctured. Elytra scutiform, with following white marks on each elytron: one at base closer to margin than suture, one posteriad closer to suture than margin, one posteriad to second closer to margin than suture, one beneath humeral callus, four smaller marks along margin posteriad and irregularly spaced, four in semi-circle from pre- to post-medial with four smaller internal marks along suture. Ventral surface scutellate, with short setae. Legs, tarsal claws without inner tooth.

Aedeagus: heavily chitinised at apex, lightly at base, moderately long, widest pre-apically and rounded to apex, penis divided and pointed (Fig. 1AE).

*Female*

Unknown.

*Distribution*

Only known from outer Perth suburbs on coastal plain of WA.

### Remarks

This species only occurs in WA and has a different colour and male genitalia (Fig. 1AE) from any other WA species.

*Etymology*
The species is named for its beauty *speciosus* L., beautiful.

**Cisseis stellata** sp. nov.
(FIGS 1Y, 2a)

*Holotype*: ♂, Cairns, SAMA I 21 524.

*Allotype*: ♀, Cairns, SAMA I 21 525.

*Paratypes*: Qld: ♂, ♀, Bowen, A. Simson, SAMA; ♂, Cooktown, Blackburn, SAMA; 2 ♀♀, Townsville, Dodd; ♀, 74, C. Yanek, SAMA; ♀, Port Denison, Blackburn, SAMA; ♀, Rockhampton, C. Vallis, SAMA; ♀, Endeavor R., M. M., SAMA; 2 ♀♀, SAMA; 2 ♂♂, Cairns, A. P. Dodd, QMBA; ♂, ♀, Cairns, J. A. Anderson, QMBA; ♀ Mt Spec, 13.i.65, J. G. Brooks, ANIC; 2 ♂♂, Black Mt. Rd Kuranda, i.1970, QMBA; ♂, ♀, Paluma, 12.i.1979, S. Barker, SAMA; 3 ♂♂, Black Mt. Rd Kuranda, 30.i.1979, QMBA; 2 ♀♀, Yeppoon, i.1950, E. C. V., QMBA; 2 ♂♂, Cardwell, Broadbent, i.1889, QMBA; ♂, Lockerbie area, Cape York, 14-18.iv.1973, G. B. Monteith, QMBA; ♀, Lockerbie area, Cape York, 13-27.iv.1973, G. B. Monteith, QMBA; 5 ♂♂, 2 ♀♀, Mourangee, Qld, 20.ii.1993, E. E. Adams, MHSA; ♂, Cape York, Daemel, HUMB; ♂, 2 ♀♀, Rockhampton, HUMB; ♂, Bloomfield River, N. Queensland, HUMB; 4 ♀♀, Cape Bedford, HUMB; ♂, ♀, 17.43S 145.03E Kennedy Hwy, ca 8km SW of Mount Garnet, 18.i.1995, J. Balderson, B. P. Moore, P. K. Christensen, JBQA; ♂, ♀, 18.03S 144.52E Kennedy Hwy, ca 60km ESE of Mount Surprise, 31.i.1995, J. Balderson, P. K. Christensen, JBQA; ♂ Marsupial Ck., E of Croydon, 20.ii.1996, J. Hasenpusch, JBQA; 15 ♂♂, 5 ♀♀, 5 km W Hidden Valley via Paluma, 10.i.2000, E. M. S. Hanlon, M. Powell, MHSA, MPWA; ♀ Davies creek 15.xi.2000, Hovorka leg., NMPC; ♂, ♀, Cape York, Thoren, NRSS; 2 ♂♂, 2 ♀♀, S Johnstone R., H. W Brown, MHSA.

*Male*
Size: 10.9 x 4.3 mm (43).
Colour: head, antennae, pronotum and scutellum coppery or green with yellow reflections. Elytra black with clumps of setae forming white spots. Ventral surface black with white markings. Legs black.
Shape and sculpture: head with prominent median sulcus, inter-antennal bridge 0.17 inter ocular width. Pronotum punctured medially, striolate laterally; apical margin projecting medially; dorsal carina diverging from ventral carina at basal margin then more or less parallel until post-medially then converging towards ventral carina but not meeting it, space between two and between angled part of dorsal carina and anterior margin filled with dense, pubescent setae. Scutellum scutiform, flat without punctures. Elytra medially punctate, laterally scutellate; with following white spots on each elytron, four in circle from pre-medial to pre-apical with one or two small in centre and two or three small along basal margin and one small pre-apical. Ventral surface medially glabrous, laterally faintly striolate; with short setae except on glabrous edges of abdominal sterna, laterally with clumps of longer setae on abdominal sterna. Legs: tarsal claws with inner tooth; meta-tibial setigeris from before middle to near distal end on three prominent ridges.
Aedeagus: mostly heavily chitinised, lightly at base, widest pre-apically, tapered to apex (Fig. 1Y).

*Female*
Size: 12.0 x 4.5 mm (35).
Colour: as in male.
Shape and sculpture: as in male.

### Remarks

This species is closest to *C. signaticollis* (Hope), the only other large, spotted species with black elytra. The pronotum of *C. signaticollis* has a bow-shaped dorsal carina and a round fovea filled with pubescent setae on either side of the mid-line closer to the basal than apical margin. The pronotum of *C. stellata* sp. nov. has a straighter dorsal carina and no setae filled fovea. Male genitalia in both are heavily chitinised and their structure is similar (Fig. 1Z).

*Etymology*
The species is named for its elytral markings, *stellatus* L., spotted.

**Cisseis trimentula** sp. nov.
(FIGS 1G, 2t)

*Holotype*: ♂, Burma Road Pilliga East SF, NSW, on *Dodonaea* sp., 16.ix.90, S. Watkins, SAMA I 21 526.

*Allotype*: ♀, same data as holotype, SAMA I 21 527.

*Paratypes*: NSW: ♂, ♀, Sydney, 4.i.06, Blackburn, NMVA; 2 ♂♂, 2 ♀♀, Hornsby, xii.60, L. Fellers, ANIC; ♀, Lane Cove, Sydney, 7.xii.62, L. Fellers, MNAG; 2 ♂♂, Ingleside, 11.ii.1984, foliage of

*Acacia longifolia*, S. Watkins, SAMA; ♀, Menai, 5.i.1985, *Acacia linifolia*, S. Watkins, SAMA; ♀ Garawilla turnoff SWest of Mullalay, 22.xi.1985, on *Leptospermum*, S. Watkins, SAMA; ♂, Menai, 3.i.1987, *Acacia linifolia*, S. Watkins, SAMA; , Burma Road Pilliga East SF, 14.xi.89, *Baeckea* sp., S. Watkins, SAMA; ♂, ♀, Burma Road Pilliga East SF via Coonabarrabran, on *Dodonaea* sp., 6.ix.1990, S. Watkins, ANIC; ♂, ♀, Sydney, ANIC; ♀, Sydney, SAMA; 3 ♂♂, Sydney dist., R. J. Burton, SAMA; ♂, ♀, Blue Mts, SAMA; 2 ♀♀, Sydney, QMBA; ♂, no data, SAMA. Qld: ♀, Bunya Mtns, 10.xii.25, H. Hacker, QMBA; 2 ♀♀, Milmerran, 12.xii.43, J. Macqueen, ANIC; ♀, 11.45S 142.35E, 1km S of Heathlands, 24.vii.1992, at light, P. Zborowski, E. S. Nielsen, ANIC; 7 ♂♂, 1 ♀♀, 16 km W of Paluma, 10.i.2000, on *Jacksonia thesiodes*, T. M. S. Hanlon, M. Powell, MHSA, MPWA, ACT; ♀, 35.15S 148.57E, Uriarra Crossing, i.1989, *Bursaria* flowers, C. Reid, ANIC. Vic.: ♀, Inglewood, 27.xii.47, C. Oke, NMVA; ♂, ♀, Inglewood, J. E. Dixon, ANIC; ♂, no data, HUMB. SA: ♀, Quorn, Blackburn, SAMA.

*Male*

Size: 4.9 x 1.9 mm (23).

Colour: Head black with green reflections apically, bronze reflections basally. Antennomeres 1-2 black with bronze reflections; 3-11 black. Pronotum black with bronze reflections in middle at apical margin and along basal margin, rest with blue reflections. Scutellum bronze. Elytra black with bronze reflections along apical margin and down suture and with obscure markings formed from setae. Ventral surface black. Legs black with bronze reflections on dorsal surface of femora.

Shape and sculpture: head punctured with deep median fovea, inter-antennal bridge 0.3 inter-ocular width. Pronotum striolate, apical margin projecting medially, basal margin sinuate, with a broad, shallow basal fovea on each side closer to basal than apical margin, dorsal carina diverging from lateral margin at basal margin, more or less parallel to it until diverging strongly post-medially to meet apical margin. Scutellum scutiform. Elytra scutellate, with clumps of short setae forming obscure patterns commencing posterior to base, with a pre-apical and apical fascia. Ventral surface striolate on thoracic sterna and laterally on abdominal sterna, glabrous in middle of abdomen, with short setae. Legs: tarsal claws with inner tooth.

Aedeagus: heavily chitinised at apex, moderately at base, elongate, with long accessory structures on each side attached laterally towards base, each ending in a setal brush; penis with long point (Fig. 1G).

*Female*

Size: 5.0 x 2.1 mm (26).

Colour: head black with bronze reflections, otherwise as in male.

Shape and sculpture: as in male.

## Remarks

This species is similar to the following one; the differences are discussed under the following Remarks.

*Etymology*

Named for the structure of the male genitalia *tre* (three *mentulus* L., penis.

### *Cisseis watkinsi* sp. nov.
(FIGS 1J, 2n)

*Holotype*: ♂, Manning River at Tinonee Rd via Wingham, NSW, *Waterhousea*, 21.xi.1993, S. Watkins, SAMA I 21 528.

*Allotype*: ♀, same data as holotype, SAMA I 21 529.

*Paratypes*: NSW: ♀, Charity ck bridge via Mount George Manning River, on *Acacia* foliage, 18.xi.1991, S. Watkins ANIC; 2 ♂♂, Wingham Brush Manning River, *Waterhousea*, 3/8.xi.1993, S. Watkins SAMA; 2 ♂♂, ♀, Manning River at Tinonee Rd via Wingham, *Waterhousea*, 11. xi.1993, S. Watkins, ANIC; 2 ♂♂, Wingham Brush Manning River, *Waterhousea*, 14.xi.1993, S. Watkins, ANIC; 3 ♂♂, Manning River at Tinonee Rd via Wingham, *Waterhousea*, 16.xi.1993, S. Watkins, SAMA; 2 ♂♂, Wingham Brush, Manning River, *Waterhousea*, 17.xi.93, S. Watkins, ANIC, SAMA; 6 ♂♂, 5 ♀♀, same data as holotype, ANIC; ♂, Gloucester River near Bundook, *Acmena smithii*, 25.xi.1993, S. Watkins, SAMA; 2 ♀♀, Wingham Brush Manning River, *Waterhousea floribunda*, 25/27.xi.1993, S. Watkins, SAMA; ♂, ♀, Manning River at Wingham, *Waterhousea*, 16/24.xii.1993, S. Watkins, SAMA; ♂, ♀, Manning River at Tinonee Rd via Wingham, *Waterhousea*, 25.xii.1993, S. Watkins, SAMA; 2 ♂♂, Manning River at Tinonee Rd via Wingham, *Waterhousea*, 9.xi.1994, S. Watkins, SAMA; ♂, ♀, Upper Williams R., x.1926, Lea, Wilson, SAMA. Qld: ♀, National Park, H. Hacker, xi.1920, NMVA.

*Male*

Size: 4.7 x 1.9 mm (24).

Colour: head dull green or blue. Antennomeres: 1-3 dull green or blue; 4-11 black with green or blue reflections. Pronotum black with yellow reflections. Scutellum gold. Elytra black with white patterns formed from clumped setae. Ventral surface and legs black.

Shape and sculpture: head setose, with deep median sulcus and medial fovea on each side, inter-antennal bridge 0.2 inter-ocular width. Pronotum striolate, with large, double basal fovea on each side; anterior margin projecting medially, dorsal carina angled outwards from base, then approaching the ventral carina post medially, not reaching anterior margin. Scutellum cordiform, punctured, anterior margin straight. Elytra covered with setae forming irregular patterns. Ventral surface faintly scutellate with short setae. Legs: tarsal claws with small inner tooth.

Aedeagus: heavily chitinised, moderately long, widest pre-apically, tapered to apex, penis pointed (Fig. 1J).

*Female*

Size: 5.2 x 2.1 mm (14).

Colour: head gold. Antennomeres: 1-5 gold; 6-11 black. Pronotum black with gold reflections. Scutellum gold. Elytra black with white patterns. Ventral surface black. Legs black, distal ends of dorsal femora with gold reflections.

Shape and sculpture: as in male.

## Remarks

This species appears similar to *C. trimentula* sp. nov. These two species can be distinguished by the differences in width - *C. trimentula* is the broader species, the size of the inter-antennal bridge - larger in *C. trimentula*, the structure of the dorsal carina on the pronotum which strongly diverges from the lateral margin to meet the apical margin in *C. trimentula* and does not in *C. watkinsi* sp. nov. and the structure of the aedeagus which has no accessory structures in *C. watkinsi* sp. nov. (Fig. 1J).

*Etymology*

The species is named after the late S. Watkins who has been of immense assistance to my research.


## Acknowledgments

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# MOSQUITOES (DIPTERA: CULICIDAE) IN METROPOLITAN ADELAIDE, SOUTH AUSTRALIA

*By* CRAIG R. WILLIAMS*, MICHAEL J. KOKKINN*, AMY E. SNELL*†, STEPHEN R. FRICKER* & EMMA L. CROSSFIELD*

## Summary

Williams, C. R., Kokkinn, M. J., Snell, A. E., Fricker, S. R. & Crossfield, E. L. (2001) Mosquitoes (Diptera: Culicidae) in metropolitan Adelaide, South Australia. Trans. R. Soc. S. Aust. 125(2), 115-121, 30 November, 2001.

The diversity and seasonal abundance of mosquito communities in metropolitan Adelaide were studied from 1998-2000. Dry-ice baited miniature light traps set at 10 sites captured adults of 16 mosquito species, while the larvae of nine species were collected from water bodies. Despite spatial and temporal heterogeneity both within and amongst sampling sites, Culex quinquefasciatus Say and Ochlerotatus notoscriptus (Skuse) were the most common species, comprising 46.9% and 27.8% respectively of the entire catch. These two species utilise man-made water bodies for larval habitat. Only Cx. Quinquefasciatus, Oc. notoscriptus and Oc. vigilax (Skuse) occurred in sufficient numbers to warrant population control measures.

Key Words: Mosquitoes, seasonal abundance, urban, Adelaide, South Australia, Ochlerotatus notoscriptus, Culex quinquefasciatus.

*Transactions of the Royal Society of S. Aust.* (2001), **125**(2), 115-121.

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KEY WORDS: Mosquitoes, seasonal abundance, urban, Adelaide, South Australia, *Ochlerotatus notoscriptus*, *Culex quinquefasciatus*.

## Introduction

Mosquitoes (Diptera: Culicidae) pose a nuisance and disease risk for both human and other animal populations. In Australia, several mosquito species act as vectors for (mostly zoonotic) viral illnesses in humans and livestock (see Russell 1995, 1998, Mackenzie *et al.* 1998 for reviews) and for canine heartworm caused by the filarial nematode *Dirofilaria immitis* Leidy (Russell 1985; Russell & Geary 1992). For any given location, the risk of human infection with mosquito-borne virus is dependent upon the mosquito and vertebrate host species present. Hence, the management of mosquitoes and mosquito-borne illness is contingent upon an understanding of mosquito community dynamics and diversity. In this study, mosquitoes were investigated in the Adelaide metropolitan area where most of the South Australian population is concentrated.

In the last published investigation of Adelaide's mosquitoes (Borthwick 1923), four species were recorded in parklands near the current Central Business District (CBD). Since then, references to common species have been made only periodically[1] (Hayes 1972; Williams *et al.* 1999; Snell & Kokkinn 2001). An examination of the South Australian Museum's entomological collection revealed that nine mosquito species from urban Adelaide have been identified since 1889 (C. R. Williams unpub.). To date there has been no systematic mosquito sampling in Adelaide, probably due to the lack of mosquito-borne human illness there.

In these studies we aimed to determine the diversity and seasonal abundance of mosquito communities in metropolitan Adelaide and describe spatial variation.

## Materials and Methods

The Adelaide CBD (34°55′ S, 138°33′ E) is surrounded by a tract of suburbia (here named metropolitan Adelaide) extending approximately 60 km from north to south, and 20 km from east to west (Fig. 1).

From 1998 to 2000, ten sites representing the majority of landscape types present in metropolitan Adelaide were sampled for mosquitoes. These were a suburban residence (Kingswood), a caravan park (West Beach), a racecourse (Morphettville), a gully with a stream (Sturt River Gorge at Flagstaff Hill), manicured parklands featuring streams, drains, and/or constructed ponds (South Parklands adjacent to the Adelaide CBD and Oaklands Park), constructed wetlands with aquatic vegetation (Bedford Park and St Peters) and grassland featuring a stream (Brownhill Creek adjacent to the southern perimeter of Adelaide Airport). Coastal residences adjacent to samphire (*Sarcocornia* A. J. Scott) and mangrove (*Avicennia marina* (Forsskal)) saline swamps at Globe Derby Park were also sampled (Fig. 1).

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[1] STAPLETON, J. L. (1984) Oviposition and Larval Ecology of the Mosquitoes *Aedes notoscriptus* (Skuse) and *Aedes camptorhynchus* (Thomson) near Adelaide South Australia. Zoology Dept, Univ. Adelaide (unpub.)

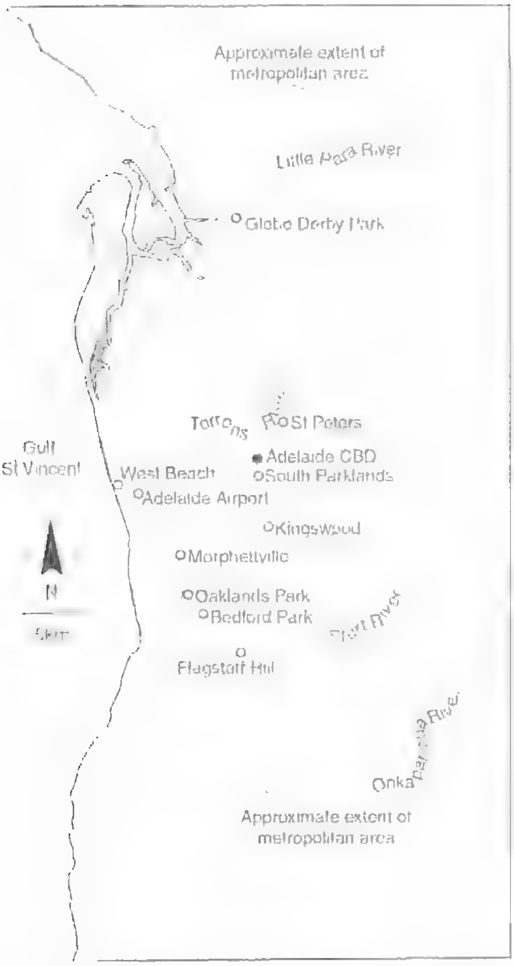


Fig. 1. Map of Adelaide, South Australia showing sampling sites and extent of metropolitan area.

Adult mosquito populations were sampled using dry-ice baited miniature light traps (Rohe & Fall 1979). These traps predominantly capture host-seeking adult female mosquitoes. The traps were set 1.5-2 m above ground level in trees approximately one hour prior to sunset and retrieved one hour after sunrise to ensure that crepuscular species were sampled. Mosquitoes were identified using the keys of Lee *et al.* (1982, 1984) and Russell (1993). To identify the sources of adult mosquitoes, non-quantitative sampling of larval mosquitoes was performed at each site using a standard dipping technique. In addition, collections from water-filled containers at five residences in metropolitan Adelaide (not shown in Fig. 1) were also made. Larvae were identified using the key of Russell (1993).

Five sites were sampled during the temperate Southern Hemisphere spring, summer and autumn seasons of 1998-1999, and four sites during the summer and autumn of 1999-2000. Collections were made at Globe Derby Park during autumn 1998. *Ad hoc* trapping over three winter seasons (1997 – 1999) revealed little or no adult mosquito activity in the Adelaide metropolitan area (C. R. Williams & M. J. Kokkinn unpub.). This obviated the need for further winter trapping.

In general, traps were set overnight at each site every two or three weeks. The number of traps varied between sites. When several traps were used at once, they were set at several locations within 0.5 km².

During 1998-1999, one trap was used at each site (Flagstaff Hill, Bedford Park, Kingswood and West Beach) on 14 nights. Two traps were used in the South Parklands over the same period. During 1999-2000, six traps were used on each of 11 nights at each site (Oaklands Park, Morphettville, Adelaide Airport, St Peters). Over the same period, six traps were used on each of seven nights at both Flagstaff Hill and Bedford Park. Data collected from these two sites in 1999-2000 were used to determine species composition but were not used in abundance and seasonal comparisons between sites. Trapping was spread evenly across the seasons.

The mean number of female mosquitoes captured per trap per night at each site was used for all statistical analyses. For each site mosquito abundance for each season was compared using either the Mann-Whitney U-test (with the Normal Approximation, Z) or an analysis of variance by ranks, namely the Kruskal-Wallis test (with the Chi-Square Approximation, $\chi^2_1$ (Zar 1984). These analyses were performed using JMP-IN® statistical software (SAS Institute 1997). When significant seasonal effects were detected by Kruskal-Wallis tests, a non-parametric multiple comparison (Dunn 1964; Zar 1984) was used to determine where differences lay. For each season and year, mosquito abundance was compared between sites using the aforementioned statistical techniques.

## Results

Sixteen species were identified from 7,326 female mosquitoes captured on 419 trap nights (Table 1). These encompassed five genera, namely *Anopheles*, *Coquillettidia*, *Culex*, *Ochlerotatus* and *Tripteroides*.

While up to 12 species were trapped at any one site, the mosquito fauna was numerically dominated by very few taxa, with others present in very small numbers. *Culex quinquefasciatus* Say and *Ochlerotatus notoscriptus* (Skuse) comprised 46.9% and 27.8% respectively of the total catch (Table 1), although the dominant species varied between sites.

In the South Parklands, *Cx. quinquefasciatus*

TABLE 1 *Totals of mosquito species captured using carbon dioxide baited miniature light traps at nine sites in metropolitan Adelaide, South Australia from 1998-2000.*

| Species | South Parklands | Residence Kingswood | Sturt R. Gorge Flagstaff Hill | Warriparinga Bedford Park | Caravan Park West Beach | Billabong St Peters | Brownhill Ck Adel. Airport | Parklands Oaklands Park | Racecourse Morphettville | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| *Anopheles amictus* Edwards | - | | 1 (0.3)[A] | | - | - | - | - | - | 1 (0.01) |
| *An. annulipes s.l.* Walker | 10 (0.6) | 3 (0.6) | 132 (33.7) | 112 (43.4) | 3 (0.7) | 378 (20.0) | 106 (8.3) | 36 (5.3) | 19 (5.8) | 799 (10.91) |
| *Coquillettidia linealis* (Skuse) | - | - | | - | - | 13 (0.7) | - | 6 (0.9) | - | 19 (0.26) |
| *Culex annulirostris* Skuse | 2 (0.1) | | 4 (1.0) | 4 (1.6) | 1 (0.2) | 60 (3.2) | 31 (2.4) | 3 (0.4) | 3 (0.9) | 108 (1.47) |
| *Cx. australicus* Dobrotworsky & Drummond | 101 (7.0) | 7 (1.3) | 5 (1.3) | 8 (3.1) | 5 (1.2) | 46 (2.4) | 53 (4.2) | 6 (0.9) | 7 (2.1) | 238 (3.25) |
| *Cx. globocoxitus* Dobrotworsky | 1 (0.06) | 1 (0.2) | 5 (1.3) | | 2 (0.5) | - | 7 (0.5) | 1 (0.1) | 79 (24.1) | 96 (1.31) |
| *Cx. molestus* Forsskal | - | - | - | 1 (0.4) | 315 (76.6) | - | - | 6 (0.9) | 5 (1.5) | 327 (4.47) |
| *Cx. quinquefasciatus* Say | 1351 (87.0) | 39 (7.3) | 28 (7.0) | 59 (22.9) | 74 (18.0) | 581 (30.7) | 988 (77.5) | 77 (25.8) | 141 (43.0) | 3438 (46.93) |
| *Ochlerotatus alboannulatus* (Macquart) | - | 2 (0.4) | 34 (9.0) | 11 (4.3) | - | 13 (0.7) | 1 (0.1) | 2 (0.3) | - | 63 (0.86) |
| *Oc. alternans* (Westwood) | | | - | - | | | 1 (0.1) | - | - | 1 (0.01) |
| *Oc. campto-rhynchus* (Thomson) | 5 (0.3) | 1 (0.2) | 5 (1.3) | 1 (0.4) | 10 (2.4) | 12 (0.6) | 60 (4.7) | 3 (0.4) | 3 (0.9) | 100 (1.37) |
| *Oc. eidsvoldensis* (Mackerras) | | - | | | - | | | - | 1 (0.3) | 1 (0.01) |
| *Oc. notoscriptus* (Skuse) | 80 (5.0) | 478 (89.0) | 138 (35.2) | 61 (23.6) | | 758 (40.0) | 26 (2.0) | 423 (61.8) | 70 (21.3) | 2034 (27.76) |
| *Oc. rubrithorax* (Macquart) | - | - | 39 (10.0) | 1 (0.4) | - | - | | | | 40 (0.55) |
| *Oc. vigilax* (Skuse) | - | | | - | 1 (0.2) | | | 13 (1.9) | - | 14 (0.19) |
| *Tripteroides atripes* (Skuse) | - | 4 (0.7) | 1 (0.3) | - | - | 31 (1.6) | 2 (0.2) | 9 (1.3) | - | 47 (0.64) |
| total mosquitoes | 1550 | 535 | 392 | 258 | 411 | 1892 | 1275 | 685 | 328 | 7326 |
| trap nights[B] | 25 | 14 | 53 | 53 | 14 | 66 | 66 | 64 | 64 | 419 |
| mean mosquitoes / trap (± SEM) | 62 (± 25.1) | 38.2 (± 10.5) | 7.4 (± 3.6) | 4.9 (± 0.8) | 29.4 (± 10.4) | 28.7 (± 4.4) | 19.3 (± 3.5) | 10.7 (± 1.3) | 5.1 (± 1.1) | 17.5 (± 2.8) |

[A] The percentage of the catch that each species comprises is given in parentheses.
[B] Two traps set for one night and 1 trap set for two nights both constitute two (2) trap nights.

formed 87% of the catch (Table 1). This contrasted with the Kingswood residence which was dominated by *Oc. notoscriptus*, comprising 89% of the catch (Table 1). Numerical dominance was demonstrated by *Culex molestus* Forsskal at the West Beach Caravan Park (76.6%) and by *Cx. quinquefasciatus* at Adelaide Airport (77.5%). Collections from the remaining sites were dominated by a mixture of two to three of the aforementioned species (Table 1).

In April 1998 at Globe Derby Park, 6,395 mosquitoes (not included in the aforementioned total) were captured using six traps per night over eight nights. *Ochlerotatus vigilax* (Skuse) comprised 83.8% of this catch (mean per trap per night = 111.6).

Statistically significant seasonal effects were observed at the South Parklands ($\chi^2 = 6.99$, $p = 0.03$), St Peters ($Z = 2.46$, $p = 0.01$) and Adelaide Airport ($Z = 2.01$, $p = 0.04$) (Figs 2, 3). Abundance was greatest in summer at all three sites. No distinct

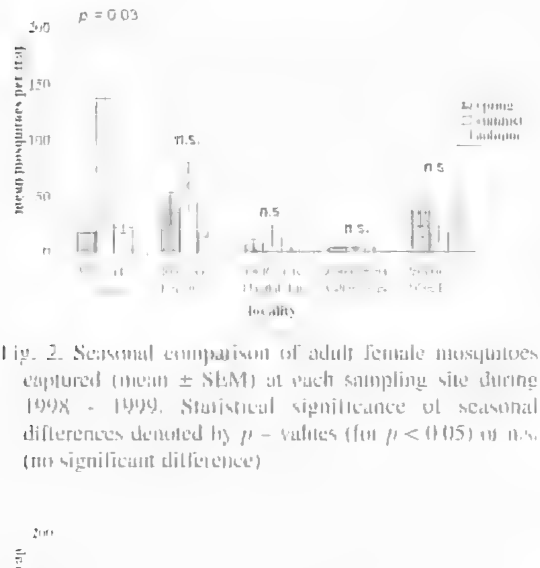


Fig. 2. Seasonal comparison of adult female mosquitoes captured (mean ± SEM) at each sampling site during 1998 - 1999. Statistical significance of seasonal differences denoted by $p$ - values (for $p < 0.05$) or n.s. (no significant difference).

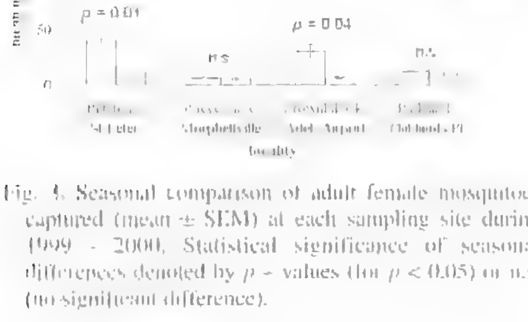


Fig. 3. Seasonal comparison of adult female mosquitoes captured (mean ± SEM) at each sampling site during 1999 - 2000. Statistical significance of seasonal differences denoted by $p$ - values (for $p < 0.05$) or n.s. (no significant difference).

seasonal effects were observed at other locations (Figs 2, 3).

Mosquito abundance differed between sites. In the summer of 1998-1999, abundance in the South Parklands and at Kingswood was significantly greater than at Bedford Park ($\chi^2 = 13.91$, $p = 0.008$). In the following autumn, South Parklands mosquito numbers were significantly higher than at Flagstaff Hill ($\chi^2 = 12.61$, $p = 0.01$). In the summer of 1999-2000, abundance at St Peters and Adelaide Airport was significantly higher than at Morphettville ($\chi^2 = 14.83$, $p = 0.002$). No significant differences were detected between sites during the following autumn ($\chi^2 = 3.97$, $p = 0.26$)

Nine species of larvae were identified in 102 collections from water bodies (Table 2). The most commonly encountered species were *Cx. quinquefasciatus* (28.4% of positive collections), *Oc. vigilax* (14.7%) and *Oc. notoscriptus* (12.7%).

## Discussion

The mosquito fauna of Adelaide is predominated by *Cx. quinquefasciatus* and *Oc. notoscriptus*. The former is most common in metropolitan parklands (54 per trap per night in the South Parklands), the latter in suburban residences (34.1 per trap per night at Kingswood) and parklands amongst densely populated residential areas (11.5 per trap per night at St Peters). Both species are able to use artificial water bodies for larval habitat. *Culex quinquefasciatus* utilises eutrophic water in drains and large water-filled containers while *Oc. notoscriptus* is found in a wide variety of small water-filled vessels, garden accoutrements and rainwater tanks (Hamlyn-Harris 1929; Lee *et al.* 1982, 1989; Table 2).

In a few localities, saline swamp species such as *Oc. vigilax* (at Globe Derby Park) and freshwater pond species such as *Anopheles annulipes s.l.* Walker (at Flagstaff Hill, Bedford Park and St Peters) are prominent. *Anopheles annulipes*, *Cx. annulirostris*, *Cx. australicus*, *Cx. quinquefasciatus*, *Oc. camptorhynchus* and *Oc. notoscriptus* are ubiquitous throughout Adelaide.

While mosquito abundance was greatest during summer at three sites (South Parklands, St Peters and Adelaide Airport), no other statistically significant seasonal effects were apparent (Figs 2, 3). At several sites there was no discernible summer peak in mosquito abundance.

Human activity provides a number of mosquito habitats in metropolitan Adelaide. In addition to man-made vessels, drains and wetlands, irrigation of parklands provides water-filled grassy depressions which act as larval habitat for *Culex* spp. (Table 2). Given that the two most common species in Adelaide

TABLE 2. *Mosquito larvae identified from different aquatic habitats in metropolitan Adelaide, South Australia from 1998-2000.*

| Sample site | Habitat type | Species collected | No. of positive collections |
|---|---|---|---|
| South Parklands | Creekline pools | *Cx. quinquefasciatus* | 3 |
| | | *Oc. alboannulatus* | 1 |
| | Pools in earthen drain | *Cx. quinquefasciatus* | 4 |
| | Pools in concrete drain | *Cx. quinquefasciatus* | 1 |
| | Water-filled grassy depression | *Cx. australicus* | 2 |
| | | *Cx. quinquefasciatus* | 3 |
| | Water-filled tree-holes | *Tp. atripes* | 1 |
| | | *Oc. notoscriptus* | 2 |
| Sturt River Gorge, Flagstaff Hill | Vegetated fringes of Sturt River | *An. annulipes* | 3 |
| | | *Cx. annulirostris* | 1 |
| | | *Cx. australicus* | 2 |
| | | *Cx. globocoxitus* | 1 |
| | | *Cx. quinquefasciatus* | 2 |
| | | *Oc. alboannulatus* | 1 |
| | | *Oc. rubrithorax* | 1 |
| | Water-filled grassy depression | *Cx. annulirostris* | 1 |
| | | *Cx. australicus* | 2 |
| | | *Cx. quinquefasciatus* | 2 |
| Warriparinga, Bedford Park | Vegetated fringes of constructed wetland | *An. annulipes* | 8 |
| | | *Cx. annulirostris* | 4 |
| | | *Cx. quinquefasciatus* | 1 |
| Brownhill Ck, Adelaide Airport | Rock pools, Brownhill Ck | *Cx. quinquefasciatus* | 2 |
| | Water-filled car tyres | *Cx. quinquefasciatus* | 1 |
| | Pools in concrete drains | *An. annulipes* | 1 |
| | | *Cx. globocoxitus* | 1 |
| | | *Cx. quinquefasciatus* | 3 |
| Racecourse, Morphettville | Pools in concrete drains | *Cx. quinquefasciatus* | 6 |
| | Water-filled grassy depression | *Cx. quinquefasciatus* | 1 |
| Globe Derby Park | Samphire swamp (predominantly *Sarcocornia* sp.) inundated by tides | *Oc. campto-rhynchus* | 7 |
| | | *Oc. vigilax* | 15 |
| Urban residences (includes those at sites on map and five additional homes) | Water-filled tree holes | *Oc. notoscriptus* | 1 |
| | Water-filled ceramic plant pots | *Oc. notoscriptus* | 2 |
| | Water-filled car tyres | *Oc. notoscriptus* | 1 |
| | Disused fish ponds | *Cx. australicus* | 2 |
| | Water-filled buckets | *Cx. quinquefasciatus* | 3 |
| | | *Oc. notoscriptus* | 2 |
| | Rain water tanks | *Oc. notoscriptus* | 5 |
| | Concrete drains | *Cx. quinquefasciatus* | 1 |
| | Concrete bird-baths and fountains | *Cx. quinquefasciatus* | 2 |
| Total no. of positive collections | | | 102 |

(*Cx. quinquefasciatus* and *Oc. notoscriptus*) utilise man-made habitats, it follows that human activity profoundly influences local mosquito communities.

Consequently, the reduction of *Cx. quinquefasciatus* and *Oc. notoscriptus* populations may be possible through public education about the nature of their larval habitats. Vigilance by residents to minimise the occurrence of water-filled vessels, and design of wetlands and drains to minimise mosquito breeding are potential mosquito control measures.

For *Oc. vigilax* larvae, which occur in saline, inter-tidal swamps, control may be possible through the application of larvicides or insect growth regulators (Mosquito Control Association of Australia 1998). Alternatively, habitat modification may be employed, whereby ephemeral pools used by mosquito larvae are more frequently inundated or are prevented from forming. This may be achieved by impoundment or by cutting channels to improve tidal flushing of such pools (Hulsman *et al.* 1989; Mosquito Control Association of Australia 1998). Control methods for *Oc. vigilax* in Adelaide are currently being investigated (C. R. Williams & M. J. Kokkinn unpub.)

Similarities exist between Adelaide's mosquito fauna and that of other Australian cites with temperate climates. Twelve of 19 species identified in urban Sydney in 1997-1998[1], 13 of 15 species in urban Melbourne in 1998 – 1999 (Wishart 1999) and 10 of 22 species identified in urban Perth (in another biogeographic region) from 1990 - 1999 (M. D. Lindsay, Univ. of Western Australia, pers. comm. 1999) were present in Adelaide. *Anopheles annulipes*, *Cx. annulirostris*, *Cx. australicus*, *Cx. molestus*, *Cx. quinquefasciatus*, *Oc. notoscriptus* and *Oc. camptorhynchus* were common to all four cities.

Several mosquito species identified in this study are known vectors of pathogens. *Culex quinquefasciatus* is a vector of canine heartworm (Russell 1985) but is considered an inefficient and unlikely vector of arboviruses in Australia[1]. *Ochlerotatus notoscriptus* is a potential vector of Ross River virus (RR) (Watson & Kay 1998), Barmah Forest virus (Watson & Kay 1999), and an efficient vector of canine heartworm (Russell & Geary 1992). Although *Cx. molestus* has been shown to carry Murray Valley Encephalitis virus in laboratory studies (McLean 1953), its true vector potential is unknown. *Culex australicus* is thought to prefer avian hosts to humans for blood meals (Kay *et al.* 1985) and is not considered an immediate risk to human health.

*Ochlerotatus camptorhynchus* and *Oc. vigilax* are primary vectors of RR in coastal temperate Australia, while *Cx. annulirostris* is the major vector in inland, riverine areas (Russell 1995). Despite the abundance of *Oc. vigilax* at Globe Derby Park there are few cases of locally acquired arbovirus infection in Adelaide (C. Horwood, South Australian Department of Human Services, pers. comm. 1998). Nonetheless, any development of land and waterways in metropolitan Adelaide must be assessed with regard to the impact upon the diversity and abundance of mosquitoes, as well as any concomitant health implications.

[1] Russell, R. C., Clancy, J. G., Doggett, S. L., Haniotis, J., Hueston, L., Marchetti, M. & Dwyer, D. (1998) "New South Wales Arbovirus Surveillance & Mosquito Monitoring Program 1997-1998" Arbovirus Disease Control Advisory Group, New South Wales Department of Health unpubl.

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# A NEW SPECIES, PRETESTIS LATICAECUM, (TREMATODA: CLADORCHIIDAE), FROM EMYDURA KREFFTII GRAY, 1871 (PLEURODIRA: CHELIDAE) FROM CENTRAL QUEENSLAND, AUSTRALIA

*By M. A. Ferguson*, L. R. Smales* & T. H. Cribb†*

**Summary**

Ferguson, M. A., Smales, L. R. & Cribb, T. H. (2001) A new species, Pretestis laticaecum, (Trematoda: Cladorchiidae) from Emydura krefftii Gray, 1871 (Pleurodira: Chelidae) from Central Queensland, Australia. Trans. R. Soc. S. Aust. 125(2), 123-127, 30 November, 2001.

Pretestis laticaecum is described from the small intestine of the freshwater turtle Emydura krefftii. The new species can be distinguished from its congener P. australianus by the following characters: significantly smaller ovary, main lymph vessels reach anterior to posterior testis, genital atrium in mid-oesophageal region, small vitelline follicles clumped around the ovary and significantly larger caeca overlapping. The position of this species and related genera in fish, the life cycle of P. australianus and the presence of P. laticaecum in turtles suggest that it is a relatively recent host capture.

Key Words: Emydura krefftii, freshwater turtle, trematode, amphistome.

*Transactions of the Royal Society of S. Aust.* (2001), **125**(2), 123-127

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## Summary

Ferguson, M. A., Smales, L. R. & Cribb, T. H. (2001) A new species, *Pretestis laticaecum*, (Trematoda: Cladorchiidae) from *Emydura krefftii* Gray, 1871 (Pleurodira: Chelidae) from Central Queensland, Australia. *Trans. R. Soc. S. Aust.* **125** (2), 123-127, 30 November, 2001.

*Pretestis laticaecum* is described from the small intestine of the freshwater turtle *Emydura krefftii*. The new species can be distinguished from its congener *P. australianus* by the following characters: significantly smaller ovary, main lymph vessels reach anterior to posterior testis, genital atrium in mid-oesophageal region, small vitelline follicles clumped around the ovary and significantly larger caeca overlapping. The position of this species and related genera in fish, the life cycle of *P. australianus* and the presence of *P. laticaecum* in turtles suggest that it is a relatively recent host capture.

Key Words: *Emydura krefftii*, freshwater turtle, trematode, amphistome.

## Introduction

Only 11 species of amphistome trematodes have been reported from Australia; eight of these are endemic (Sey 1991). Of the endemic species *Macropotrema pertinax* Blair, Beveridge & Speare, 1979 (Zygocotylidae Sey, 1988), and *Gemellicotyle wallabicola* Prudhoe, 1975 (Paramphistomidae Fischoeder, 1901) occur in macropodid marsupials, *Australodiscus megalorchis* (Johnston, 1912) (Diplodiscidae Skrjabin, 1949) occurs in amphibians, *Pretestis australianus* Angel & Manter, 1970, *Australotrema brisbanense* Khalil, 1981, *Bancroftrema neoceratodi* Angel, 1966 (all Cladorchiidae Southwell et Kirshner, 1932) occur in fish and *Lobatodiscus australiensis* Rohde, 1984 and *Elseyatrema microacetabularis* Rohde, 1984 (both Cladorchiidae) occur in turtles (Sey 1991). These latter two species occur in the freshwater turtle *Elseya dentata* Gray, 1836.

With the exception of *Carettochelys insculpta* from New Guinea and the Northern Territory, all Australian freshwater turtles belong to the Order Pleurodira, characterised by horizontal flexion of the neck vertebrae during head retraction, Family Chelidae, a group that has no fossil record outside its present distribution, Australia and South America (Ernst & Barbour 1989). *Emydura krefftii* is distributed across most of eastern Queensland (Cann 1998) and is common in larger rivers, waterholes, billabongs and associated floodplains (Cogger 1992). Juvenile *Emydura* species are mainly carnivorous but increase the proportions of other food types as they mature (Georges 1982) and become omnivorous, opportunistic feeders which adapt to local availability of food (Cann 1998).

During a survey of freshwater turtles from the Fitzroy River catchment in Central Queensland, three of 51 *Em. krefftii* were found to harbour a previously undescribed amphistome species. Examination showed this to be a new species of *Pretestis*, which is described below.

## Materials and Methods

Turtles were captured using drum nets and hand lines baited with ox heart. Turtles were euthanased with a cervical injection of Nembutal (sodium pentobarbitone) and all organs examined under a dissecting microscope for helminths. Trematodes were fixed unflattened in near-boiling formalin, stained with Gower's carmine and mounted in Canada balsam. Drawings were made with the aid of a drawing tube. All measurements are in micrometres given as the range followed by the mean in parentheses.

All work for this project was carried out under Central Queensland University Animal Ethics Approval No. 95/7-105 and all collections were made under Queensland Environmental Protection Agency permits N0/001662/97/SAA and C6/000077/98/SAA. Specimens have been deposited in the South Australian Museum, Adelaide (SAMA) and the Queensland Museum, Brisbane (QMB).

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### *Pretestis laticaecum* sp. nov. (FIGS 1-5)

*Holotype*: from the lower small intestine of *Emydura krefftii* Gray, Fitzroy River, Queensland (23° 22' S, 150° 32' E), coll M. Ferguson, 17/ix/1996 QMB218302.

*Paratypes*: 21 specimens SAMA AHC28364.

*Description of adult*

(Measurements of 20 specimens, types). Body cylindrical, 833-1105 (941) long, round in cross section, 187-374 (251) at widest point. Pharynx 102-132 (111) long x 66-82 (75) wide, cup-shaped and strongly muscularised, with anterior sphincter. Large extramural pharyngeal sacs, 59-99 (81) long x 56-82 (67) wide. Oesophagus 148-270 (213) long with oesophageal bulb 33-42 (36) long x 46-66 (51) wide. Caeca short, 231-448 (302) x 69-127 (92) wide, occupying middle third of body, with thin muscular walls and a thick layer of glandular tissue. Ventral sucker ventroterminal, 154-247 (197) long x 201-268 (130) wide, well muscularised. Lymph glands large, opening through y-shaped pore in cup of ventral sucker, main paired lymph vessels extending to just past posterior testis. Excretory bladder y-shaped, excretory pore dorsal, posterior, exiting just anterior to margin of acetabulum. Testes two, oblique, round to slightly oval. Anterior testis 69-105 (89) diameter, precaecal, submidline. Posterior testis 75-145 (106) diameter, intracaecal, midline. Ovary midline, oval, 36-39 (38) long, intracaecal, directly posterior to posterior testis. Laurer's canal opening on dorsal surface posterior to ovary. Vitelline follicles intracaecal, extending from just behind posterior testis to just past termination of caeca. Uterus intracaecal. No eggs present. Cirrus-sac with vesicula seminalis interna. Cirrus spined. Gonopore midline, 171-264 (221) from anterior, at margin of anterior testis, just posterior to diverticula. Distinct eyespots in mid-oesophageal zone.

*Description of redia*

Body cylindrical, 850-952 (895) long x 170-306 (221) wide. Large oral opening with muscular pharynx 142-165 (149) long x 112-132 (124) wide, without extramural sacs. Sac-like intestine 288-409 (346) long x 134-268 (230) wide. Up to six developing cercariae in body of redia.

*Description of cercaria*

Body oval to elongate 630-710 (662) x 208-302 (259), heavily pigmented. Tail simple, shorter than body 677-710 (693) x 94-127 (103), attached dorsal to ventral sucker. Pharynx 58-94 (72) x 60-101 (78) with extramural pharyngeal sacs 47-101 (60) x 67-94 (74). Oesophagus long, 107-147 (129) with oesophageal bulb. Caeca short 134-201 (171) x 13-40 (27), ending mid-body. Testes two, 34-94 (66) x 34-80 (56), anterior testis precaecal, submidline, posterior testis intracaecal, midline. Ovary small, 13-40 (25), posterior to testis. Caudal excretory tube. Large lymph vessel opening through y-shaped pore in papilla of ventral sucker. Ventral sucker ventroterminal. Genital pore at anterior margin of anterior testis. Two eyespots present, 34-87 (57) long.

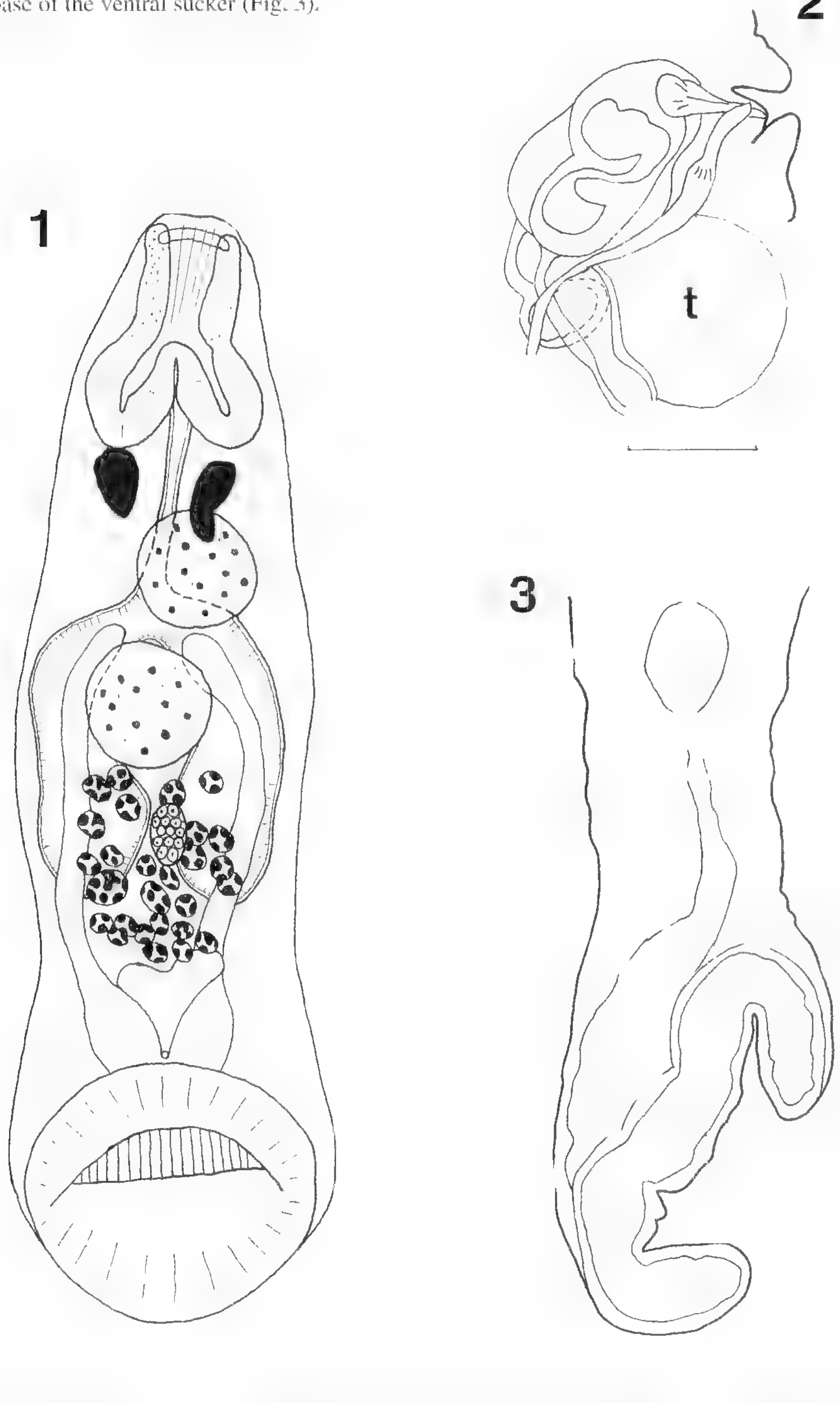
*Etymology*

The species name refers to the characteristic wide caeca.

## Remarks

*Pretestis laticaecum* sp. nov., with two testes, the anterior extracaecal, a post-testicula ovary, cirrus sac and primary pharyngeal sacs, is clearly a member of the family Cladorchiidae, Subfamily Sandoniinae Ukoli, 1972. Of the four genera comprising the Sandoniinae, *P. laticaecum* falls within the monospecific genus *Pretestis* Angel & Manter 1970, as it has a cylindrical body shape, ventral sucker smaller than the body width with an oval aperture and caeca that terminate midbody. Of the other three genera of the Sandoniinae, the new species can be excluded from *Basidiodiscus* Fischthal & Kuntz, 1959, because the acetabulum is smaller than the body width and without papilloform projections. It can be excluded from *Sandonia* McClelland, 1957 because the caecal termination and ovary are midbody, and do not reach to the level of the acetabulum. *Australotrema* Khalil, 1981, has tandem testis and an acetabulum with a transverse opening and strong sphincter, characters absent from *P. laticaecum*.

The new species can be distinguished from *P. australianus* in having a smaller ovary 36-39 µm compared to 530-840 µm long. The main lymph vessels in *P. australianus* reach only to the level of the ovary, whereas the main lymph vessels in *P. laticaecum* reach a point in front of the posterior testis (Fig. 1). The genital atrium in *P. australianus* is mid-oesophageal (Angel & Manter 1970), whereas in the new species it sits on the anterior margin of the anterior testis (Fig. 2). The caeca of all specimens of *P. laticaecum* are very wide and, in many specimens, overlap centrally, whereas in *P. australianus* they are slender and distinctly separate. Finally, the vitelline follicles of the new species are not "considerably large" (Sey 1991) and the follicles are clumped around the ovary, whereas in *P. australianus* they are in two distinct fields which align with the caeca and are not confluent posteriorly. A single papilla can be seen in the base of the ventral sucker (Fig. 3).



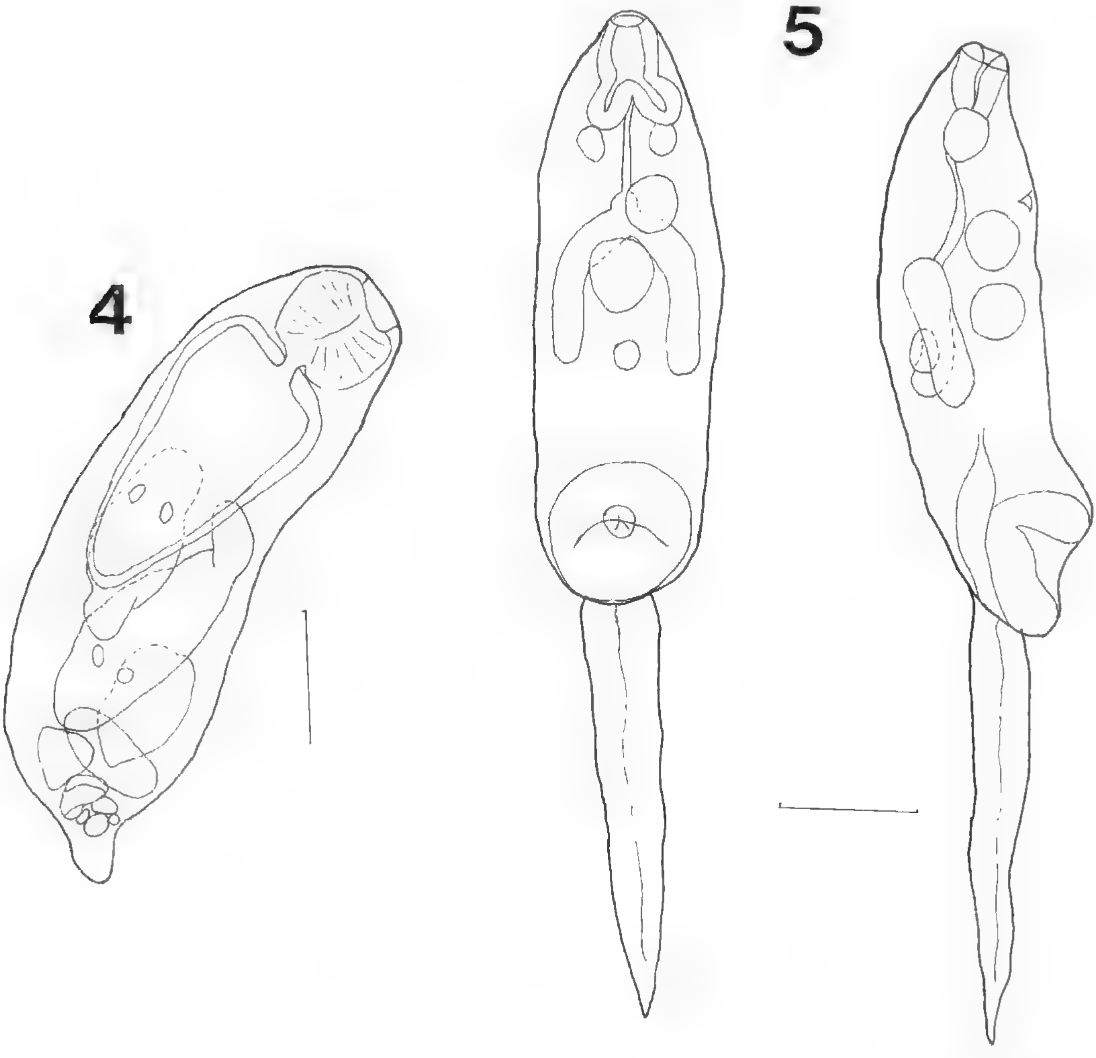

Figs 1-3. *Pretestis laticaecum* sp. nov. 1. Adult, ventral view. 2. Cirrus sac, lateral view. 3. Ventral sucker papilla, lateral view.

Angel & Manter (1970) mention "cercarial eyespots" in their specimens, and anterior pigmentation in this area, presumably as a result of disrupted eyespots. The specimens we examined had large amounts of sperm stored in the vesicula seminalis interna and a single egg has been recorded. All of the specimens we examined had eyespots and we therefore consider them to be a feature of adults.

## Discussion

The subfamily Sandoniinae comprises three monotypic genera plus *Pretestis*, all species with the exception of *P. laticaecum*, occurring in fish (Sey 1991). *Sandonia sudanensis* McClelland, 1957 and *Basidiodiscus ectorchis* Fischthal & Kuntz, 1959 are from North Africa (Egypt, Ghana, Niger and Sudan), *P. australianus* and *A. brisbanense* are from Australia. This modern disjunct distribution suggests Gondwanan origins for the group (Sey 1991). As all other representatives of the Sandoniinae occur in fish, *Pretestis laticaecum* may be an example of recent host capture.

The fish hosts for *P. australianus* commonly occur in coastal rivers and estuaries in Queensland (Grant 1982). Angel & Manter (1970) observed the metacercariae of *P. australianus* encysting on filamentous algae. Probably the fish become infected when they eat such algae and presumably turtles become infected the same way.




Figs 4-5. *Pretestis laticaecum* sp. nov. 4. Redia, ventral view. 5. Cercaria, ventral and lateral view. t: anterior testis. Scale bars = 1, 3-5 200 mm; 2, 50 mm.

The rediae (Fig. 4) and cercariae (Fig. 5) were recovered from the snail host *Thiara balonennsis*, Conrad. The cercariae especially have many of the features of the adult, including the distinctive pharyngeal sacs, eyespots, alignment of the testes, small ovary, short caeca and papilla in the ventral sucker.

*Emydura krefftii* has a sympatric distribution with *Em. macquarii* Gray, 1830 in southern Queensland, the northern part of *Em. macquarii*'s range (Cann 1998), and the two species have similar dietary habits. No amphistomes however have been found in *Em. macquarii*[1].

All other amphistomes known from turtles, also cladorchids, are included in the subfamilies Nematophilinae, Schizamphistominae and Caballerodiscinae. The previously known Australian representatives, *L. australiensis* and *E. microacetabularis*, are placed within the latter two subfamilies, and are thought to represent both a Gondwanan distribution (*Elseyatrema*) and parallel evolution (*Lobatodiscus*) (Sey 1991).

[1] Jul. Sey (1976) Studies on trematodes (Plagiorchiata) from Australian freshwater turtles. PhD thesis, University of Queensland (unpub)

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# A NEW SPECIES OF EIMERIA (APICOMPLEXA: EIMERIIDAE) FROM THE BRUSHTAIL POSSUM, TRICHOSURUS VULPECULA (DIPROTODONTIA: PHALANGERIDAE)

*By Michael G. O'Callaghan* & Peter J. O'Donoghue†*

## Summary

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A new species of Eimeria is described from the brushtail possum (Trichosurus vulpecula). Fifty (24%) of 212 faecal samples were positive for coccidia. Sporulated oocysts of the new species are ellipsoidal to cylindrical, slightly pointed at one end, 41.4 x 22.7 $\mu$m, with a double oocyst wall, micropyle, oocyst residuum and refractile polar granule. Each oocyst contains four ellipsoidal to pyriform sporocysts 15.6 x 9.9 $\mu$m, with a Stieda body, sub-Stieda body and sporocyst residuum. Each sporocyst contains two sporozoites completely filling the sporocyst and containing a large and small refractile globule.

Key Words: Coccidia, Eimeria, Eimeria trichosuri sp. nov., brushtail possum, Trichosurus vulpecula.

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Key Words: Coccidia, *Eimeria*, *Eimeria trichosuri* sp. nov., brushtail possum, *Trichosurus vulpecula*.

## Introduction

The common brushtail possum is one of the most familiar of Australian native animals inhabiting most cities. Three genera belonging to the Family Phalangeridae occur in Australia: *Phalanger*, the cuscuses, of which there are two species inhabiting northern Queensland, *Trichosurus*, the brushtail possums and *Wyulda squamicaudata* Alexander, 1918, the scaley tailed possum (Schink *et al.* 1992). The northern brushtail possum, *T. arnhemensis* Collette, 1897 inhabits north-western tropical Australia, the mountain brushtail, *T. caninus* (Ogilby, 1836), inhabits high country in eastern Australia while the common brushtail, *T. vulpecula* (Kerr, 1792), is the most widely distributed, occupying eastern, central, western and southern Australia including Tasmania and also New Zealand, where it has been introduced (Schink *et al.* 1992). It is arboreal and nocturnal and spends the day in the hollow of a tree.

Although *Eimeria* species have been reported in brushtail possums in Australia (Presidente *et al.* 1982; O'Callaghan & Moore 1986; Viggers & Spratt 1995) and in New Zealand (Stankiewicz *et al.* 1996, 1997a, b, 1998) no *Eimeria* species has been described nor named from brushtails nor any member of the Family Phalangeridae. Here we describe a new species of *Eimeria* found in *Trichosurus vulpecula* from several localities in Australia and New Zealand.

## Materials and Methods

Most faecal samples examined were collected from live-trapped possums captured in Queensland, Victoria, Tasmania and South Australia in 1994 and 1995; the remaining samples were collected from dead animals in New Zealand and from the ground in Tasmania in 2001. Faecal samples were transported to the laboratory and examined for the presence of coccidia following a centrifugal flotation in saturated magnesium sulphate solution (SG 1.30). Positive samples were placed into 2% aqueous (w/v) potassium dichromate and stored at room temperature for up to 12 weeks. Sporulated oocysts were recovered in magnesium sulphate solution and examined under an oil immersion 100x objective in an Olympus microscope fitted with a Nomarski differential interference contrast system. Measurements were made with an eyepiece graticule calibrated with an ocular micrometer. All measurements in the text are given in micrometers (µm) as mean ± standard deviation with range in parentheses. A phototype of unsporulated and sporulated oocyst has been deposited in the US National Museum, Beltsville, Maryland, Parasite Collection (USNPC No. 91524).

## Results

Oocysts were recovered from faecal samples of 50 (24%) *T. vulpecula* collected at 15 localities in eastern and southern Australia and two in New

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TABLE 1. *Material examined, localities, year of collection and number of samples positive for oocysts of* Eimeria trichosuri

| Locality | | Year | No. collected | No. positive |
|---|---|---|---|---|
| Tasmania, Launceston | | | | |
| | Suburban | 1994 & 2001 | 11 | 3 |
| | Rural | 1994 & 2001 | 34 | 5 |
| | Upper Blessington | 2001 | 6 | 3 |
| Victoria | Sutton Grange | 1994 | 19 | 5 |
| | Axe Creek | 1994 | 1 | 0 |
| | Culgoa Mallee | 1994 | 4 | 0 |
| | Tang Swamp | 1994 | 12 | 3 |
| | unidentified | 1994 | 4 | 1 |
| South Australia | | | | |
| | Adelaide | 1995 | 10 | 0 |
| | Kangaroo Island | 1995 | 30 | 6 |
| Queensland | | | | |
| | Brisbane | 1995 | 19 | 0 |
| | Rockhampton | 1995 | 23 | 6 |
| | Townsville | | | |
| | Pallerenda | 1995 | 6 | 1 |
| | City | 1995 | 16 | 9 |
| New Zealand | | | | |
| | Bulls | 2001 | 12 | 6 |
| | Taniha | 2001 | 5 | 2 |
| Total | | | 212 | 50 |

Zealand (Table 1). Morphological characters conform to those of the genus *Eimeria* in that they contain four sporocysts per oocyst and two sporozoites per sporocyst. The coccidia were identified as a new species of *Eimeria* which is described below.

**_Eimeria trichosuri_** sp. nov.
(FIGS 1-4)

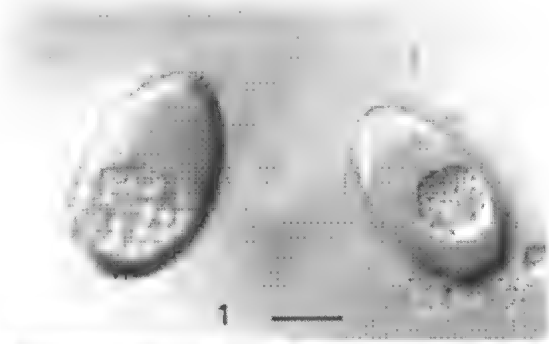
*Material examined*

Oocysts in faeces from four animals, from Sutton Grange, Townsville, Launceston and Bulls.

*Phototypes*: Holotype from faeces of *T. vulpecula* Townsville, Queensland; paratype from faeces of *T. vulpecula* Launceston, Tasmania (USNPC No. 91524).

*Description*

Sporulated oocyst (n=120) ellipsoidal to cylindrical: 41.4 ± 3.20 (34.4 - 49.2) x 22.7 ± 2.67 (18.4 - 27.8) with a length:width ratio 1.8 (1.3-2.6); double oocyst wall, outer wall smooth, occasionally stippled at micropylar end, colourless to yellow, 1.6-2.0 in thickness; inner wall clear, colourless, 1.0 thick, oocyst residuum consisting of globules up to 3.0 in diameter, occurring either as a loose aggregate or scattered throughout oocyst; micropyle present, 3.2-4.0 wide. 1-2 refractile bodies present, occasionally disintegrated; 4 ellipsoidal to pyriform sporocysts (n=110) 15.6 ± 1.02 (13.0 -18.0) x 9.9 ±





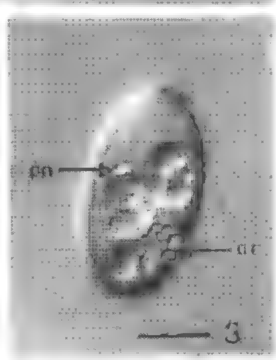



Fig. 1. Unsporulated oocysts of *Eimeria trichosuri* sp. nov. Scale bar = 14 μm.
Figs 2, 3. Sporulated oocysts of *E. trichosuri* sp. nov. Abbreviations: pg, polar granule; or, oocyst residuum. Scale bars = 14 μm.

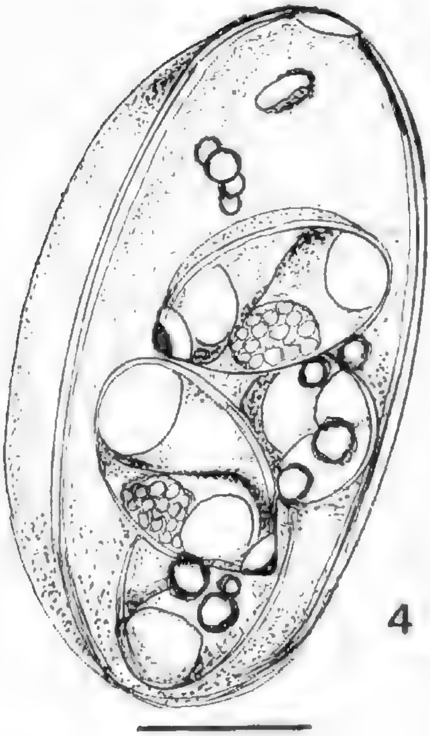


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Fig. 4. Composite line drawing of sporulated oocyst of *E. trichosuri* sp. nov. Scale bar = 10 µm.

0.69 (8.2 - 12.0) with length:width ratio 1.6 (1.1 - 2.0); slightly pointed at one end with a cap or knob-like Stieda body; sub-Stieda body present; sporocyst residuum an accumulation of small globules 5.0-5.8 in diameter at equator of sporocyst; 2 sporozoites present, lying head to tail each containing a large refractile globule 5.0 in diameter and a smaller refractile globule 2.5 in diameter.

## Remarks

No *Eimeria* species have been described from the family Phalangeridae until now. Of the *Eimeria* species described from the order Diprotodontia in Australia, oocysts of the new species most closely resemble *E. gaimardi* Barker, O'Callaghan & Beveridge 1988 from *Bettongia gaimardi* (Desmarest, 1822), the Tasmanian bettong. Oocysts of the proposed species differ, however, by being larger (41.4 x 22.7 v. 34.6 x 24.3) and by possessing a micropyle. In addition, the oocyst wall of *E. gaimardi* is thinner than that of the new species and also mamillate in appearance (Barker *et al.* 1988).

*Type host*

*Trichosurus vulpecula* (Kerr, 1792) (Marsupialia: Phalangeridae), common brushtail possum.

*Type locality*

Townsville, Queensland (19° 16' S, 146° 49' E).

*Location in host*

Oocysts in faeces, developing stages unknown. However, developing stages of what may be the same species have been found previously within the intestinal tract of the same host (Presidente 1984).

*Etymology*

Specific name derived from the generic name of the host.

## Discussion

Most *Eimeria* species described from mammals are known only from oocysts recovered in faecal samples (Levine 1982). Oocyst morphology is used to identify and distinguish between *Eimeria* species although considerable variation in oocyst and sporocyst size is known to occur (Duszynski 1971). Despite some variation in size, shape and colour, the oocysts of *E. trichosuri* sp. nov. were remarkably uniform in their morphological characteristics irrespective of sampling locality or season. We conclude, therefore, that they represent a single *Eimeria* species. Dimensions of coccidian oocysts reported by Presidente (1982) in *T. vulpecula* trapped in rural and urban areas of Melbourne, correspond with the dimensions of the *Eimeria* species described here. Morphometric observations made on oocysts detected in *T. caninus* by Presidente *et al.* (1982) were also similar to those reported in this investigation, suggesting that they may be conspecific. However, further studies on the identity and distribution of *Eimeria* species infecting closely related host species are required before the biological validity of morphologically similar species can be confirmed.

Presidente (1982) did not consider coccidia infections detected in possums to be pathogenic. Subsequent studies failed to demonstrate lesions in juvenile possums infected with sporulated oocysts of an undescribed *Eimeria* species (Harrigan & Presidente, unpub. cited by Presidente 1984) and histo-pathological changes were mild in nature. Infections by coccidia in *T. vulpecula* in New Zealand were tentatively associated with diarrhoea (Hutton 1979) but in only two animals. There is little evidence to suggest that the species of *Eimeria* infecting *T. vulpecula* described in this study is pathogenic. However, the number of oocysts detected was generally low and no data are available on the effects of heavy infections in susceptible animals. Further studies are required to determine whether infections may be pathogenic under specific conditions.

## Acknowledgments

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# SPECIES OF RAILLIETINA FUHRMANN, 1920 (CESTODA: DAVAINEIDAE) FROM THE SOUTHERN CASSOWARY (CASUARIUS CASUARIUS)

*By Michael O'Callaghan*†, Ross H. Andrews*, Margaret Davis* & David M. Spratt‡*

**Summary**

O'Callaghan, M. G., Andrews, R. H., Davies, M. & Spratt, D. M. (2001) Species of Raillietina Fuhrmann, 1920 (Cestoda: Davaineidae) from the southern cassowary (Casuarius casuarius), Trans. R. Soc. S. Aust. 125(2), 133-139, 30 November, 2001.
A new species of Raillietina is described from the intestine of the southern cassowary, Casuarius casuarius, from Australia. It is a small cestode and differs from cestodes previously described from cassowaries in the size of the scolex, rostellum, rostellar hooks, suckers and cirrus sac. Raillietina casuarii is redescribed from specimens collected in Australia. Raillietina casuarii and R. infrequens were identified in a southern cassowary from New Guinea.
Key Words: Cestoda, cassowary, Raillietina, new species Casuarius casuarius.

*Transactions of the Royal Society of S. Aust.* (2001), **125**(2), 133-139.

# SPECIES OF *RAILLIETINA* FUHRMANN, 1920 (CESTODA: DAVAINEIDAE) FROM THE SOUTHERN CASSOWARY (*CASUARIUS CASUARIUS*)

by MICHAEL G. O'CALLAGHAN*†, ROSS H. ANDREWS*, MARGARET DAVIES* & DAVID M. SPRATT‡

## Summary

O'CALLAGHAN, M. G., ANDREWS, R. H., DAVIES, M. & SPRATT, D. M. (2001) Species of *Raillietina* Fuhrmann, 1920 (Cestoda: Davaineidae) from the southern cassowary (*Casuarius casuarius*). *Trans. R. Soc. S. Aust.* **125** (2), 133-139, 30 November, 2001.

A new species of *Raillietina* is described from the intestine of the southern cassowary, *Casuarius casuarius*, from Australia. It is a small cestode and differs from cestodes previously described from cassowaries in the size of the scolex, rostellum, rostellar hooks, suckers and cirrus sac. *Raillietina casuarii* is redescribed from specimens collected in Australia. *Raillietina casuarii* and *R. infrequens* were identified in a southern cassowary from New Guinea.

KEY WORDS: Cestoda, cassowary, *Raillietina*, new species, *Casuarius casuarius*.

## Introduction

Two species of *Raillietina* have been reported from Casuariidae by Kotlan (1923) who described *Raillietina casuarii* and *R. infrequens* from a large collection of parasites belonging to the Hungarian naturalist, Lewis Biró, accumulated during the years 1897-1899 from *Casuarius bennetti picticollis* Sclater, 1874 in New Guinea. More recently, Schmidt (1975) identified the same cestode species from *C. bennetti* Gould, 1858 at another location in New Guinea. The related southern cassowary, *C. casuarius* (Linnaeus, 1758), inhabits north-eastern Australia and New Guinea (Pollock 1992). In 1917, Macgillivray recorded the presence of unidentified tapeworms in the intestine of *C. casuarius johnsonii* Mueller, 1866 "bagged" on the upper Claudie River during an ornithologists' excursion to Cape York Peninsula, Queensland. In this study, we have examined the cestodes collected from nine *C. casuarius*; one from New Guinea, seven from known localities in Australia and one with no collection data. Three cestode species have been identified and all are assigned to the genus *Raillietina* Fuhrmann, 1920 (*sensu* Jones & Bray 1994) on the basis of the possession of two rows of numerous, hammer-shaped rostellar hooks, unilateral genital pores, a small cirrus sac which does not cross or just crosses the osmoregulatory canals and egg capsules containing several eggs. Here we describe a new species of *Raillietina* and report the presence of *R. casuarii* and *R. infrequens* for the first time in *C. casuarius*.

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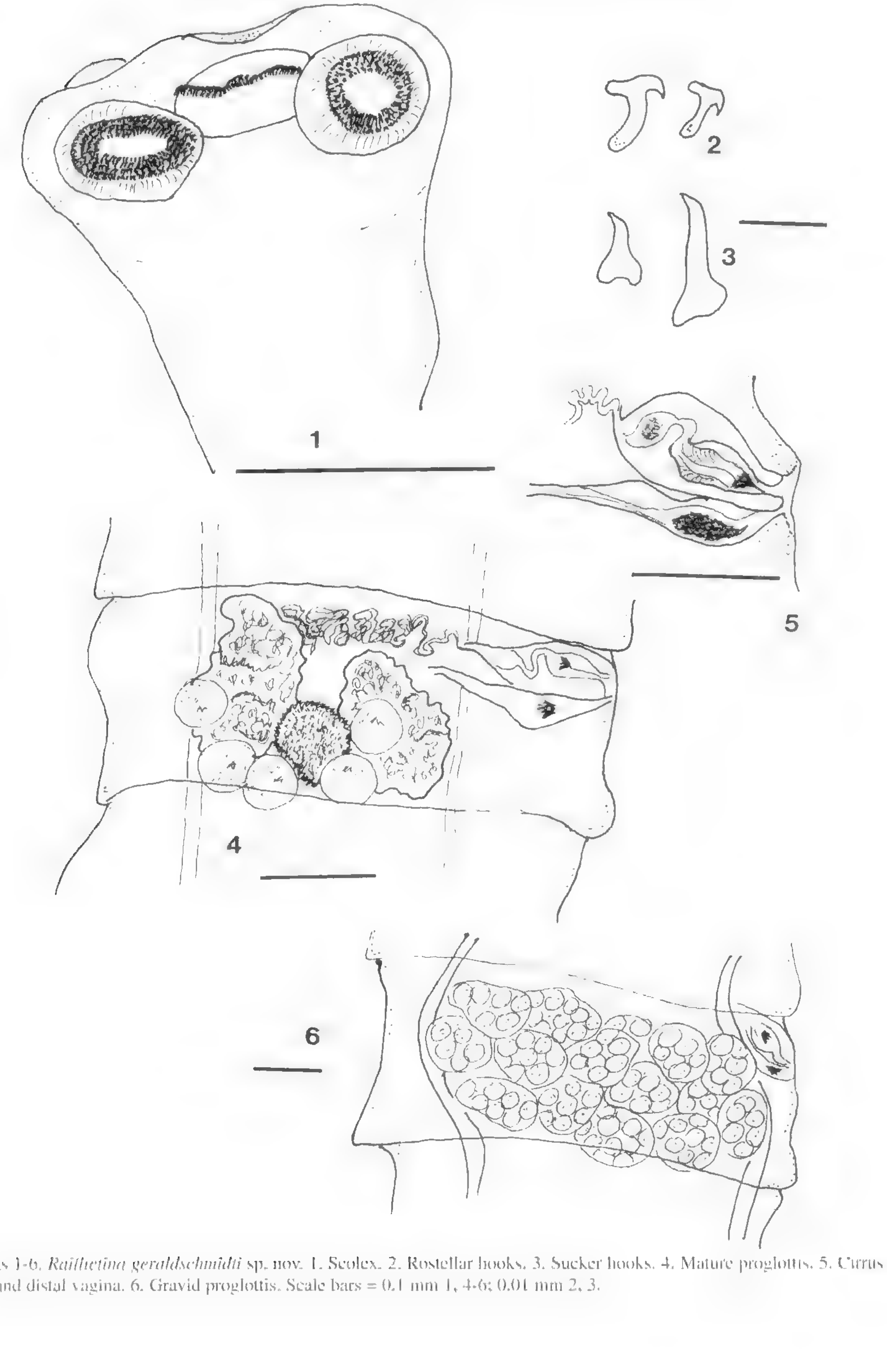
## Materials and Methods

Southern cassowaries, *C. casuarius*, were collected as road kills by staff of the Queensland National Parks and Wildlife Service and frozen. At a later date, the birds were transported to CSIRO Sustainable Ecosystems (formerly Division of Wildlife and Ecology) in Canberra where the cestodes were recovered from intestines and preserved in 10% formalin. Some of the material examined consisted of cestode fragments only. Proglottides were stained in Celestine Blue and Heidenhain's haematoxylin, dehydrated in ethanol, cleared in clove oil and mounted in Canada Balsam. Scoleces were mounted and cleared in De Fauré's medium. Measurements of the cestodes examined are given in the text, in mm, as a range followed, in parentheses, by the mean and number of observations. Illustrations were made with the aid of a camera lucida attached to an Olympus BH microscope. Type specimens have been deposited in the Australian Helminth Collection (AHC) of the South Australian Museum, Adelaide (SAMA) and in the CSIRO Wildlife Helminthological Collection, Sustainable Ecosystems, Canberra (W/L HC).

### ***Raillietina geraldschmidti*** sp. nov.
(FIGS 1-6)

*Holotype*: Scolex on slide, 2 specimens on slides, 3 specimens, Mission Beach, Qld (17° 52′ S, 146° 06′ E), coll. D. M. Spratt, 3.ix.1999, SAMA AHC 28397, 31475.




Figs 1-6. *Raillietina geraldschmidti* sp. nov. 1. Scolex. 2. Rostellar hooks. 3. Sucker hooks. 4. Mature proglottis. 5. Cirrus and distal vagina. 6. Gravid proglottis. Scale bars = 0.1 mm 1, 4-6; 0.01 mm 2, 3.

*Paratypes:* 1 slide, 2 specimens, Mission Beach, Qld (17° 52′ S, 146° 06′ E), coll. D. M. Spratt, 3.ix.1999, SAMA AHC 28398, 31476; 1 specimen, El Arish, Qld (17° 49′ S, 146° 00′ E), coll. D. M. Spratt, 28.xi.1999, SAMA AHC 31477; cestode fragments, Etty Bay, Qld (17° 34′ S, 146° 05′ E), coll. D. M. Spratt, 4.i.1998, SAMA AHC 31478; mature proglottides on slide, Mission beach, coll. F. Crome & D. M. Spratt, 7.vi.1987, SAMA AHC 28399.

*Other material:* W/L HC C941, W/L HC C939

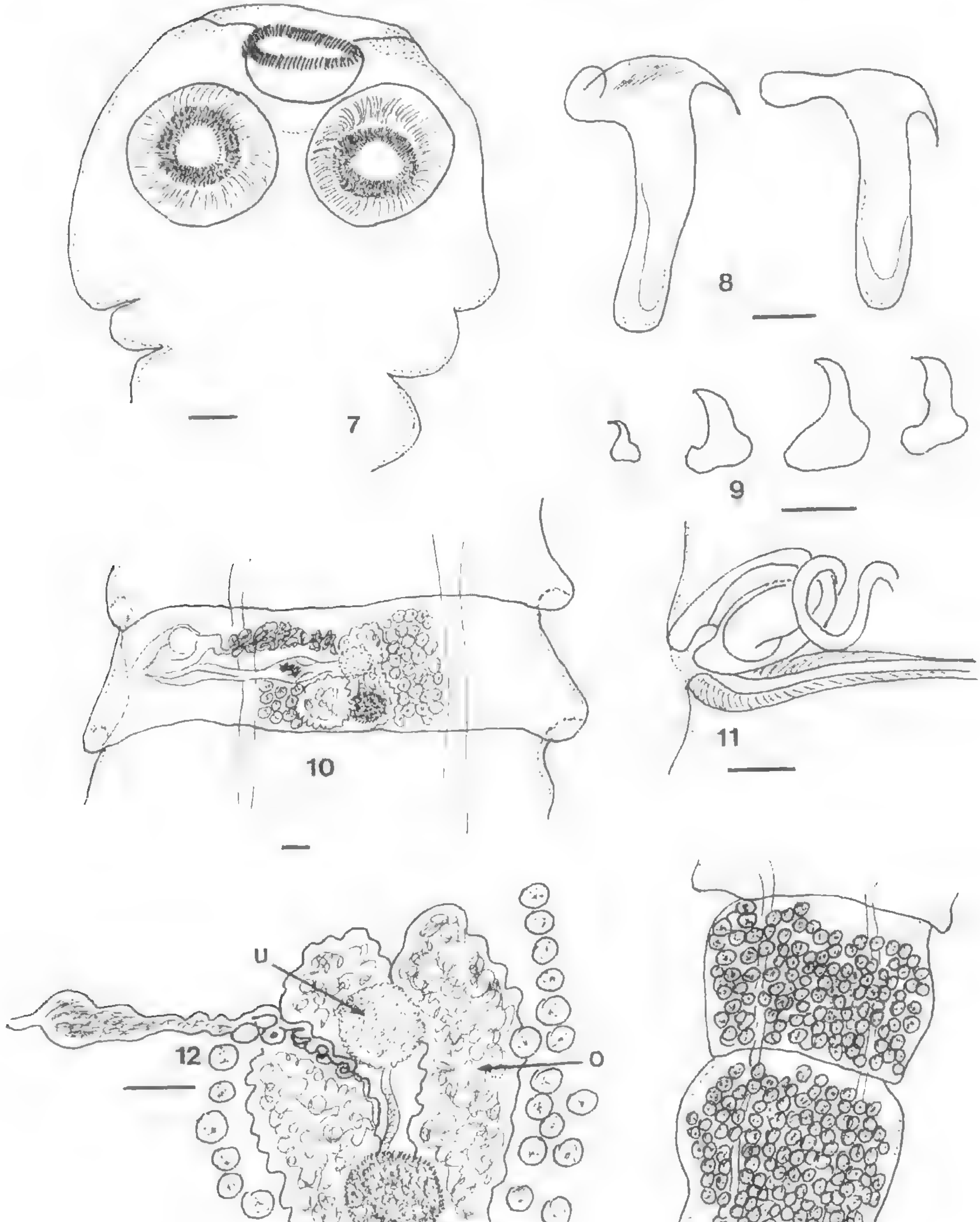
*Description*

Description based on mounted specimens of three strobilae, cestode fragments consisting of mature proglottides and two scoleces. Small cestode, maximum length 40 in relaxed specimens, maximum width 0.760. Strobilae contain approximately 450 proglottides. Scolex 0.155-0.180 (0.166, n=3) in diameter with retracted rostellum 0.064-0.074 (0.069, n=2) in diameter (Fig. 1). Rostellum armed with 218-238 (228, n=2) hammer-shaped hooks in two circular rows. Larger, anterior rostellar hooks 0.008-0.009 (0.008, n=20) in length; smaller, posterior rostellar hooks 0.007-0.008 (0.007, n=20) in length (Fig. 2). Rostellum armed with minute accessory spines 0.001 in length visible under high magnification only. Suckers 0.052-0.072 (0.059, n=8) in diameter armed with hooks 0.005-0.014 in length (Fig. 3). Proglottides acraspedote. Immature proglottides longer than wide, 0.112-0.152 (0.130) x 0.036-0.072 (0.060, n=10). Mature proglottides wider than long 0.080-0.144 (0.104) x 0.312-0.560 (0.426, n=10) (Fig. 4). Genital pores single, unilateral. Lateral dorsal osmoregulatory canals 0.028-0.036 in diameter joined by transverse commissures, 0.008 in diameter, in posterior region of proglottides. Ventral osmoregulatory canal not seen. Cirrus sac 0.108-0.124 (0.116) x 0.048- 0.052 (0.049, n=10) (Fig. 5) extending anteromedially to but not crossing lateral osmoregulatory canal. Distal region of cirrus narrow, mid region enlarged, lined with spines, proximal region forms spherical internal seminal vesicle 0.018-0.030 (0.023, n=10) in diameter. External seminal vesicle absent. Vas deferens narrow, greatly coiled, passing medially towards centre of proglottis. Testes 5-7 in number, lying within area bounded by lateral osmoregulatory canals, usually overlying ovary and vitellarium; testes 0.036-0.044 (0.039, n=10) in diameter in poral and aporal groups, 2 poral and 3-4, occasionally 5, aporal.

Vagina and cirrus opening into common genital atrium, vagina opening posterior to cirrus. Distal region of vagina enlarged, 0.040-0.048 (0.047) x 0.018-0.024 (0.022, n=10), with a seminal receptacle 0.014-0.020 (0.016, n=10) usually containing sperm. Mid-region narrow, leading medially posterior to vas deferens. Ovary bilobed, each lobe circular, lobes approximately equal in size, 0.052-0.120 (0.088) x 0.040-0.108 (0.080, n=20). Vitellarium median, post ovarian, circular 0.048-0.076 (0.062) x 0.040-0.072 (0.053, n=10). Gravid proglottides (Fig. 6) wider than long, 0.240-0.320 (0.251) x 0.480-0.736 (0.650, n=10). Egg capsules 0.072-0.080 (0.075) x 0.064-0.080 (0.066, n=5), spheroidal, 16-20 in each

TABLE 1. *Measurements of the principle features of* Raillietina *species in* Casuarius casuarius.

| | *R. casuarii* Kotlan (1923) | *R. casuarii* Amau, N. G. | *R. casuarii* El Arish, Qld | *R. infrequens* Kotlan (1923) | *R. infrequens* Amau, N. G. | *R. geraldschmidti* |
|---|---|---|---|---|---|---|
| Size (mm) | 340 x 3 | 140 x 1.5 | 200 x 3.4 | 80 x 1.2 | 50 x 0.920 | 40 x 0.760 |
| Dimensions of scolex (mm) | 1.0- 1.2 | 0.910 | 0.962 | 0.500 | 0.456 | 0.166 |
| Size of large rostellar hooks (mm) | 0.048-0.054 | 0.046-0.053 | 0.038-0.042 | 0.027-0.034 | 0.022-0.024 | 0.008-0.009 |
| Size of small rostellar hooks (mm) | 0.040-0.046 | 0.038-0.046 | 0.032-0.037 | 0.021-0.025 | 0.017-0.019 | 0.007-0.008 |
| Number of rostellar hooks | 250 | 176-212 | 172-192 | 260 | - | 218-238 |
| Diameter of suckers (mm) | 0.400 | 0.344 | 0.349 | 0.130 | 0.128 | 0.059 |
| Dimensions of cirrus sac (mm) | 0.250 x 0.160 | 0.316 x 0.102 | 0.256 x 0.146 | 0.180-0.200 x 0.060 | 0.174 x 0.056 | 0.116 x 0.049 |




Figs 7-13. *Raillietina casuarii* from Australia. 7. Scolex. 8. Rostellar hooks. 9. Sucker hooks. 10. Mature proglottis. 11. Cirrus sac and distal vagina. 12. Female genitalia. 13. Gravid proglottis. Scale bars = 0.1 mm 7, 10-13; 0.01 mm 8, 9 Legend: o, ovary; u, developing uterus; v, vitellarium.

proglottis, containing 11-13 circular eggs 0.020-0.032 (0.026, n=10) in diameter. Oncosphere circular 0.012-0.016 (0.015, n=10) in diameter, embryonic hooks 0.006 long.

*Host*

*Casuarius casuarius* Linnaeus, 1758 (Struthioniformes: Casuariidae)

*Location in host*

Intestine

*Etymology*

Named for the late Dr G. Schmidt in recognition of his outstanding contribution to our knowledge of cestodes.

## Comparison with other species

*Raillietina geraldschmidti* sp. nov. can be distinguished from congeners in the Casuariidae by size, the small rostellar hooks and small scolex (Table 1). Of the species of *Raillietina* described in the Struthioniformes, *R. geraldschmidti* most closely resembles *R. mitchelli* described recently by O'Callaghan, Davies & Andrews (2000). *Raillietina geraldschmidti* differs from *R. mitchelli* in the size of the scolex (0.166 v. 0.298), rostellar hooks (0.007-0.009 v. 0.008-0.012) and cirrus sac (0.116 x 0.049 v. 0.161 x 0.038). In addition, *R. geraldschmidti* is smaller than *R. mitchelli* and has fewer rostellar hooks (228 v. 316).

## *Raillietina casuarii* (Kotlan, 1923)
(FIGS 7-13)

*Davainea casuarii* Kotlan, 1923. Ann. Trop. Med. Parasitol. 17, 45-57. Figs 1-5.
*Raillietina (Ransomia) casuarii*: Fuhrmann, 1920
*Kotlania casuarii*: Lopez-Neyra, 1931
*Kotlanotaurus casuarii*: Spasskii, 1973
*Raillietina casuarii*: Fuhrmann, 1924

*Material examined*: 4 specimens, El Arish, Qld (17° 49' S, 146° 00' E), coll. D. M. Spratt, 28.xi.1999, SAMA AHC 31481; 12 specimens, Mission Beach, Qld, coll. D. M. Spratt, 3.ix.1999 SAMA AHC 31479, 31480; 1 specimen on slide, Queensland University, no collection data, SAMA AHC 28400; 2 strobilae on slides, 6 specimens, Amau, New Guinea (10° 02' S, 148° 40' E), coll. W. B. Hitchcock, 4.ix.1969 SAMA AHC 12878, 22349.

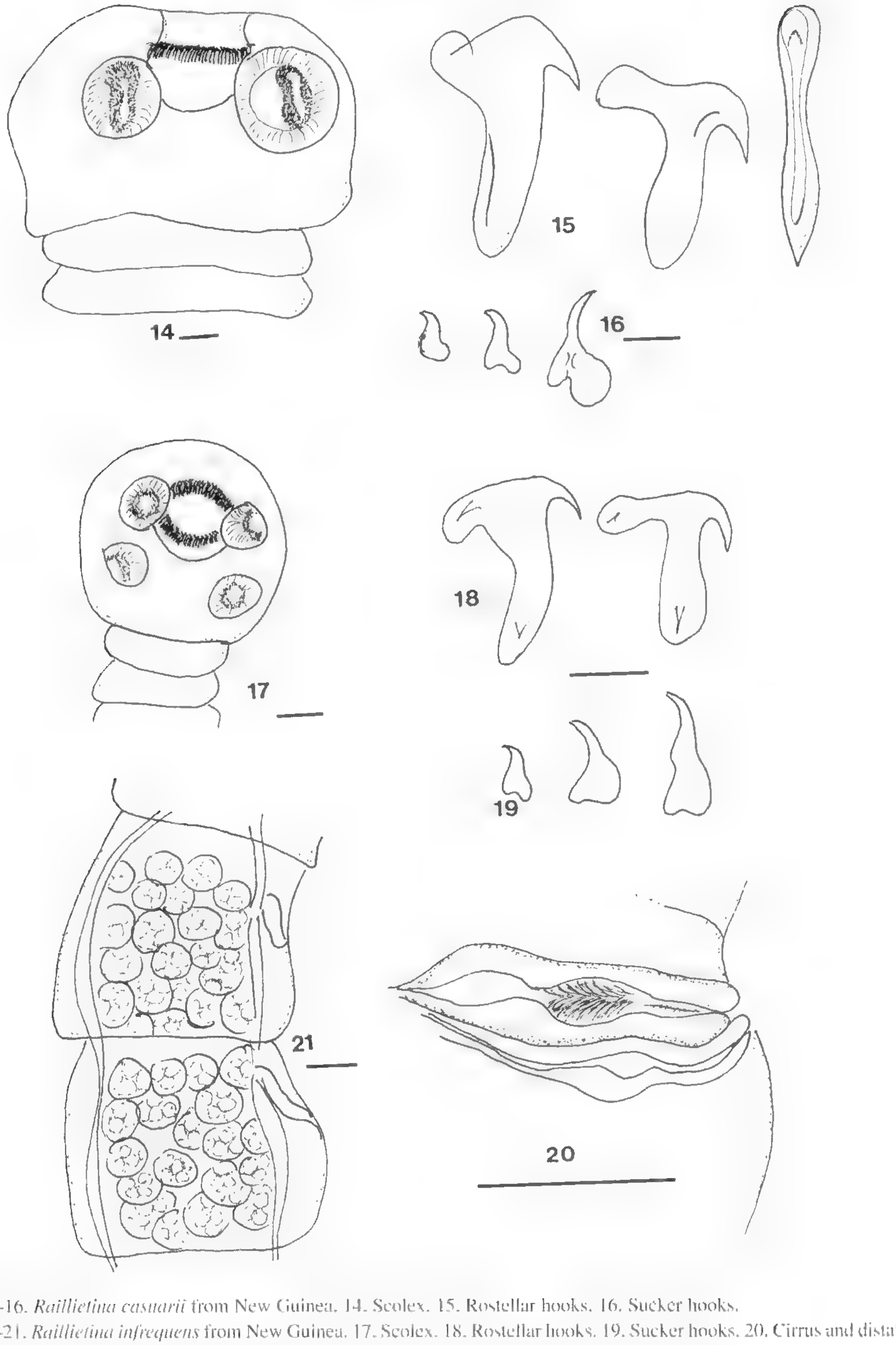
*Other material*: W/L HC C940, W/L HC 942

*Revised description*

Description based on mounted specimens of four strobilae and five cleared scoleces. Large cestode, up to 200 in unrelaxed specimens, maximum width 3.4. Strobila contains approximately 700 proglottides. Scolex 0.800-1.048 (0.962, n=5) in diameter with eversible rostellum 0.304-0.360 (0.323, n=5) in diameter (Figs 7, 14). Rostellum armed with 172-212 (190, n=9) hammer-shaped hooks in two circular rows. Larger, anterior rostellar hooks 0.038-0.053 (0.045, n= 50) in length; smaller, posterior rostellar hooks 0.032-0.046 (0.039, n=50) in length (Figs 8, 15). Rostellum armed with accessory spines 0.002-0.003 in length visible under high magnification only. Suckers, circular, 0.320-0.368 (0.347, n=9) in diameter; armed with 10-13 rows of hooks 0.005-0.021 in length (Figs 9, 16).

Proglottides craspedote. Mature proglottides wider than long 1.777-1.898 (1.836) x 0.343-0.505 (0.428, n=10) (Fig. 10). Genital pores single, unilateral. Dorsal osmoregulatory canal narrow, 0.010 in diameter, ventral osmoregulatory canal 0.040-0.064 in diameter. Narrow transverse osmoregulatory canals connect right and left dorsal and ventral canals at posterior margin of each proglottis. Large cirrus sac 0.232-0.336 (0.286) x 0.128-0.208 (0.169, n=20) extending anteriorly, not reaching lateral osmoregulatory canals. Distal region of cirrus of greater internal diameter than proximal region, armature not seen, mid-region expanding to form large internal seminal vesicle folded dorsally, 0.096-0.128 (0.102, n=10) maximum diameter (Fig. 11). Vas deferens greatly coiled passing medially towards centre of proglottis. Testes 0.048-0.056 (0.049, n=12) in diameter, number 43-51 per proglottis, always more testes on aporal field; 12-14 (13) in poral field, 31-37 (35) aporal.

Vagina opening to genital atrium posterior to male genital pore, distal region with thickened muscular wall 0.028-0.036 (0.033, n=10) wide. Mid region with thickened wall extending, uncoiled, medially and posterior to vas deferens, region internal to osmoregulatory canals dilated and filled with sperm, proximal region coiled. Ovary bilobed, poral lobe 0.200-0.240 (0.214) x 0.112-0.120 (0.115, n=5), aporal lobe 0.240-0.280 (0.269) x 0.112-0.136 (0.122, n=5) with 3-4 lobules in each lobe. Vitellarium median, post ovarian, sub-circular 0.128-0.152 (0.144) x 0.096-0.136 (0.110, n=10). Uterine duct passing anteriorly to developing uterus (Fig. 12). Gravid proglottides 1.000-2.121 (1.860) x 0.606-1.080 (0.731, n=10) (Fig. 13) filled with egg capsules. Egg capsules sub-spherical to ovoid, containing 1-4 eggs, mostly 1-2, seldom 3 or 4. Capsules containing one egg 0.052-0.072 (0.062) x 0.048-0.064 (0.056, n=10), containing two eggs 0.076-0.104 (0.091) x 0.052-0.072 (0.060, n=10). Approximately 250-300 egg capsules in each proglottis. Eggs spherical 0.040-0.052 (0.045) x




Figs 14-16. *Raillietina casuarii* from New Guinea. 14. Scolex. 15. Rostellar hooks. 16. Sucker hooks.

Figs 17-21. *Raillietina infrequens* from New Guinea. 17. Scolex. 18. Rostellar hooks. 19. Sucker hooks. 20. Cirrus and distal vagina. 21. Gravid proglottides. Scale bars = 0.1 mm 14, 17, 20, 21; 0.01 mm 15, 16, 18, 19.

0.032-0.044 (0.039, n=10) containing spherical oncosphere 0.020-0.024 (0.023) x 0.020-0.024 (0.021, n=10), embryonic hooks 0.006-0.008 long.

*Host*

*Casuarius casuarius* Linnaeus, 1758 (Struthioniformes: Casuariidae).

*Location in host*

Intestine.

### Remarks

These specimens of *R. casuarii* are smaller than those reported previously (140 v. 340) (Table 1). However, Kotlan (1923) in describing the largest cestodes from one locality, observed more contracted and shorter cestodes than those described.

### *Raillietina infrequens* (Kotlan, 1923) (FIGS 17-21)

*Davainea infrequens* Kotlan, 1923. Ann. Trop. Med. Parasitol. 17, 45-57.
*Raillietina infrequens*: Fuhrmann, 1932

*Material examined*: 1 strobila on slide, 2 specimens, Amau, New Guinea, coll. W. B. Hitchcock, 4.ix.1969 SAMA AHC 12878, 22349.

*Revised description*

Description based on one entire mounted specimen, segments of mature and gravid proglottides and one scolex. Strobilae are 50 long and contain 500 segments with characters that conform to those reported by Kotlan (1923). The scolex (Fig. 17) is 0.456 in diameter with a retracted rostellum 0.200 in diameter armed with two rows of hammer-shaped hooks that have become dislodged and some appear to be missing. Larger, anterior rostellar hooks 0.022-0.024 (0.023, n=10) in length; smaller, posterior rostellar hooks 0.017-0.019 (0.018, n=10) in length (Fig. 18). Circular suckers 0.116-0.140 (0.128, n=10) in diameter are armed with hooks 0.005-0.014 in length (Fig. 19). In mature segments genital pores are unilateral, with a cirrus sac and vagina which conform with the description and dimensions reported by Kotlan (1923). Cirrus sac 0.160-0.192 (0.174) x 0.048-0.060 (0.056, n=10) (Fig. 20). Gravid segments are wider than long (Fig. 21); up to six terminal segments 0.488-0.560 (0.537) x 0.336-0.520 (0.425) containing 25-32 (28, n=6) egg capsules each with 7-10 (9, n=10) eggs. Egg capsules circular 0.080-0.100 (0.090) x 0.072-0.088 (0.078, n=10).

*Host*

*Casuarius casuarius* Linnaeus, 1758 (Struthioniformes: Casuariidae).

*Location in host*

Intestine

### Remarks

Gravid proglottides were unavailable in the material examined by Kotlan (1923) and consequently he was unable to complete the description of *R. infrequens*. Therefore, a description of gravid segments, although from a limited number of specimens is presented here. Kotlan (1923) also estimated the size of *R. infrequens* from two fragments that apparently belonged together. The two mounted specimens of *R. infrequens* examined here are in semi-contracted form.

## Discussion

The new species of *Raillietina* described in this study appears to be restricted to the southern cassowary in Australia and does not occur in the closely related emu (O'Callaghan *et al.* 2000). Although *R. geraldschmidti* sp. nov. has not previously been reported from cassowaries in New Guinea, few birds have been examined for cestodes. Similarly, *R. infrequens* was not found in the birds examined here and may be limited to cassowaries in New Guinea. Studies of additional material will be required before the distribution of *Raillietina* species in the Casuariidae can be determined.

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# CERVONEMELLA REARDONI GEN. ET SP. NOV. (NEMATODA: CLOACINIDAE) FROM THE STOMACHS OF SCRUB WALLABIES, DORCOPSIS SPP., IN PAPUA NEW GUINEA

*By I. Beveridge**

## Summary

Beveridge, I. (2001) Cervonemella reardoni gen. et sp. nov. (Nematoda: Cloacinidae) from the stomachs of scrub wallabies, Dorcopsis spp., in Papua New Guinea. Trans. R. Soc. S. Aust. 125(2), 141-145, 30 November, 2001.

Cervonemella reardoni gen. et sp. nov. is described from the stomachs of Dorcopsis hageni Heller, 1897 and D. luctuosa (D'Albertis, 1874) from Papua New Guinea. The new species and genus are allocated to the Cloacininae Stossich, 1899 on the basis of having a large, cylindrical buccal capsule, four branches to the dorsal ray of the copulatory bursa and the externo-dorsal ray arising close to the lateral trunk. The bipartite submedian cephalic papillae indicate that the species and genus belong within the tribe Cloacininea (Stossich, 1899). The buccal capsule which is as long as wide, but lacks internal teeth, together with the anterior extensions of the intestinal cells, around the oesophageal bulb differentiate the new species from Cloacina von Linstow, 1898, Arundelia Mawson, 1977 and Beveridgea Mawson, 1980, the other genera of the Cloacininea.

Key Words: Nematoda, marsupials, wallabies, new genus, Dorcopsis.

*Transactions of the Royal Society of S. Aust.* (2001), **125**(2), 141-145

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by I. BEVERIDGE*

## Summary

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*Cervonemella reardoni* gen. et sp. nov. is described from the stomachs of *Dorcopsis hageni* Heller, 1897 and *D. luctuosa* (D'Albertis, 1874) from Papua New Guinea. The new species and genus are allocated to the Cloacininae Stossich, 1899 on the basis of having a large, cylindrical buccal capsule, four branches to the dorsal ray of the copulatory bursa and the externo-dorsal ray arising close to the lateral trunk. The bipartite submedian cephalic papillae indicate that the species and genus belong within the tribe Cloacininea (Stossich, 1899). The buccal capsule which is as long as wide, but lacks internal teeth, together with the anterior extensions of the intestinal cells around the oesophageal bulb differentiate the new species from *Cloacina* von Linstow, 1898, *Arundelia* Mawson, 1977 and *Beveridgea* Mawson, 1980, the other genera of the Cloacininea.

KEY WORDS: Nematoda, marsupials, wallabies, new genus, *Dorcopsis*.

## Introduction

The helminth parasites of forest wallabies of the genus *Dorcopsis* from Papua New Guinea are poorly known (Spratt *et al.* 1991) with current collections limited to a small range of specimens obtained from some of the more common species. Among the existing collections, Spratt *et al.* (1991) listed an undescribed genus belonging to the nematode tribe Cloacininea (Stossich, 1899) deposited in the South Australian Museum. The specimens were derived from material collected by T. Reardon from the white-striped dorcopsis, *Dorcopsis hageni* Heller, 1897, during a field trip to the Madang area of Papua New Guinea in 1987. Recent examination of nematodes from the grey dorcopsis, *Dorcopsis luctuosa* (D'Albertis, 1874) in the collections of The Natural History Museum, London, revealed an additional specimen of the genus. The new taxon is described in this paper and its affiliations with other genera in the tribe Cloacininea are discussed.

## Materials and Methods

Entire stomach contents, including parasites, were fixed in 10% formaldehyde following the death of the host. In the laboratory, nematodes were removed from stomach content, washed in water and cleared in lactophenol. Drawings were made using a drawing tube attached to an Olympus BH2 microscope. Drawings of apical views of the heads of nematodes are oriented with the dorsal aspect uppermost; drawings of the bursa have the ventral surface uppermost. Measurements were made with an ocular micrometer. All measurements are in millimetres and are presented as the range from 10 male and 5 female specimens followed by the mean in parentheses. Types of the new species have been deposited in the South Australian Museum, Adelaide (SAMA), the Natural History Museum, London (BMNH) and the United States National Parasite Collection, Beltsville, Maryland (USNPC). Host nomenclature follows Groves & Flannery (1989).

## ***Cervonemella*** gen. nov.

*Synonymy*: "Cloacininea gen. n., sp. n." of Spratt *et al.*, 1991, p. 63 (SAMA AHC 16999).

*Etymology*

The generic name is derived from *cervus*, or *cervos* in older orthography, meaning stag, but used figuratively by some Latin authors to mean "horned" and alludes to the horn like appearance of the incurved submedian cephalic papillae.

*Diagnosis*

Strongyloidea Weinland, 1863; Cloacininae Stossich, 1899; Cloacininea (Stossich, 1899); small nematodes, body covered with numerous fine annulations; cephalic collar present; 2 amphids; 4 bipartite, incurved submedian papillae; internal leaf

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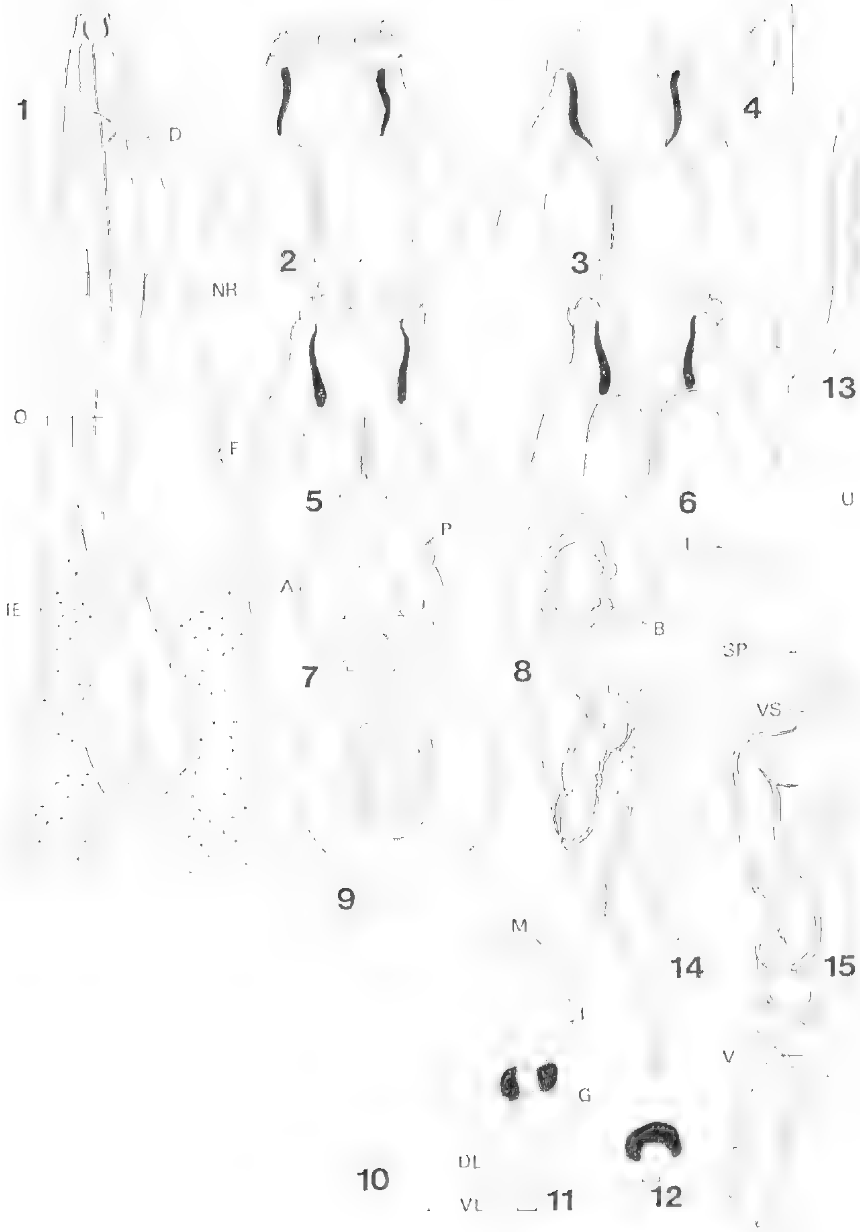


Figs 1-15. *Cervonemella reardoni* gen. et sp. nov. 1. Anterior end, lateral view. 2. Cephalic extremity, lateral view, dorsal aspect on left hand side. 3. Cephalic extremity, lateral view, median optical section, dorsal aspect on left hand side. 4. Submedian papilla, lateral view. 5. Cephalic extremity, dorsal view. 6. Cephalic extremity, dorsal view, median optical section. 7. Cephalic extremity, apical view. 8. Cephalic extremity, apical view, optical transverse section through anterior region of buccal capsule. 9. Cephalic extremity, apical view, optical transverse section through posterior region of buccal capsule. 10. Bursa, apical view. 11. Gubernaculum, spicule sheaths and genital cone, dorsal view. 12. Transverse optical section through gubernaculum. 13. Distal tip of spicule, lateral view. 14. Female tail, lateral view. 15. Female genital system, lateral view. Scale bars = 0.1 mm 1,10,14,15; 0.01 mm 2-9, 11-13. Legend : A, amphid; B, buccal capsule; D, deirid; DL, dorsal lip of genital cone; E, secretory-excretory pore; G, gubernaculum; I, infundibulum; IE, intestinal extension; L, lateral thickening of spicule sheaths; M, median thickening of spicule sheaths; NR, nerve ring; O, oesophagus; P, submedian papilla; SP, sphincter; U, uterus; V, vagina; VL, ventral lip of genital cone; VS, vestibule.

crown of 8 elements; mouth opening sub-circular; buccal capsule as long as wide, walls sclerotised; oesophagus elongate, clavate, bulb surrounded by extensions of anterior intestinal cells. Bursa short, lobes distinct; ventro-lateral and ventro-ventral rays apposed; medio-lateral and postero-lateral rays apposed; antero-lateral ray divergent, shorter; externo-dorsal ray arises close to lateral trunk; dorsal ray with 4 branches. Genital cone with conical anterior lip bearing single central papilla and posterior lip with paired papillae; median and lateral thickenings of spicule sheaths present; gubernaculum present spicules simple, elongate alate. Female tail conical; vulva immediately anterior to anus; ovejector J-shaped, sphincters and infundibula short; egg thin shelled, ellipsoidal.

Parasitic in the stomachs of macropodid marsupials.

## *Cervonemella reardoni* sp. nov.
(FIGS 1-15)

*Holotype:* ♂ from stomach of *Dorcopsis hageni* Heller, 1897, Usino, Madang, Papua New Guinea, May 1987, coll. T. Reardon, SAMA AHC 31463.

*Allotype:* ♀ same data, SAMA AHC 31464.

*Paratypes:* same data, 14♂♂, 5♀♀, SAMA AHC 31465; 1♂, BMNH 2001.4.10.14; 1♂, USNPC 91143; slide preparations of apical view of mouth and bursa SAMA AHC 28391.

*Other material examined:* from stomach of *Dorcopsis luctuosa* (D'Albertis, 1874): 1♂, Veikabu Creek, Papua New Guinea, coll. I. Owen, BMNH 1981.216.

*Site in host*

Stomach.

*Etymology*

The species is named after the collector of the types, T. Reardon, of the South Australian Museum.

*Description*

Small, slender nematodes; cuticle with numerous fine transverse annulations 0.010 apart, cervical cuticle closely applied to body, becoming slightly inflated in oesophageal region. Mouth opening sub-circular; distinct cephalic collar present, bearing 4 submedian papillae and 2 amphids. Submedian papillae elongate, divided into proximal and distal segments, projecting anteriorly from peri-oral cuticle with distal extremities incurved; proximal segment elongate, subcylindrical with outer margin convex, 0.004 long; distal segment short, ovoid, 0.0013 in diameter. Buccal capsule cylindrical, approximately as long as wide, walls sinuous in lateral and dorso-ventral views, tapering at extremities. Buccal capsule approximately hexagonal in apical view near anterior extremity, becoming approximately oval in shape near posterior end. Internal leaf crown elements 8 in number, rounded distally, arising from full length of internal wall of buccal capsule. Peri-oral cuticle not inflated into lip-like lobes attached to each leaf crown element. Oesophagus simple, elongate, claviform; anterior half broader than third quarter; distal quarter forming clavate bulb; lining of oesophagus without rows of sclerotised bosses or denticles. Nerve ring in mid-oesophageal region; deirids setiform, in anterior oesophageal region, anterior to nerve ring; secretory-excretory pore between nerve ring and oesophago-intestinal junction. Anterior intestinal cells enlarged, forming paired elongate appendages extending anteriorly alongside oesophageal bulb.

*Male*

Total length 5.1-6.8 (5.8); maximum width 0.31-0.39 (0.35); buccal capsule 0.020-0.025 (0.022) long x 0.025-0.030 (0.026) wide; oesophagus 0.56-0.71 (0.66) long; nerve ring to anterior end 0.20-0.27 (0.25); secretory-excretory pore to anterior end 0.25-0.44 (0.39); deirid to anterior end 0.08-0.17 (0.13).

Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral lobes and ventral lobes joined. Dorsal lobe similar in length to lateral lobes. Dorsal ray dividing to produce 4 branchlets; primary division occurring at mid-length, giving rise to paired external branchlets; external branchlets directed postero-laterally, not reaching margin of bursa; internal branchlets arising immediately after primary bifurcation, branchlets directed postero-laterally, almost reaching margin of bursa. Externo-dorsal ray arising close to lateral rays, not reaching margin of bursa. Postero-lateral and ventro-lateral rays apposed, reaching margin of bursa; antero-lateral ray divergent, shorter than other lateral rays; not reaching margin of bursa; ventro-lateral and ventro-ventral rays apposed, reaching margin of bursa. Gubernaculum present, heavily sclerotised, ovoid in shape, 0.020-0.030 (0.022) long x 0.040-0.050 (0.042) wide; median and paired lateral thickenings present at junction of spicule sheaths. Genital cone prominent; anterior lip conical, with single papilla at apex; posterior lip shorter than anterior lip, with pair of claviform papillae; spicules simple, elongate, with tubular shaft; proximal tips irregulary knobbed; distal tips blunt, slightly curved; spicule ala prominently ribbed, terminating distally, anterior to spicule tip, spicules 1.75-2.18 (2.01) long.

*Female*

Total length 6.8-8.9 (8.0); width at mid-body region 0.38-0.45 (0.41), body swollen in region of tail, 0.40-0.50 (0.44) in width; buccal capsule 0.020 (0.020) long by 0.027-0.030 (0.030) wide; oesophagus 0.70-0.78 (0.74) long; nerve ring to anterior end 0.25-0.30 (0.27); secretory-excretory pore to anterior end 0.40-0.47 (0.44); deirid to anterior end 0.12-0.14 (0.13).

Tail short, conical, 0.30-0.35 (0.32) long; vulva immediately anterior to anus, 0.42-0.49 (0.47) from posterior end; vagina slightly convoluted, 0.42-0.68 (0.54) long; ovejector J- shaped, sphincters and infundibula as long as or shorter than vestibule; uteri prodelphic; egg ellipsoidal, thin-shelled, 0.07-0.08 (0.07) x 0.03-0.04 (0.04).

## Discussion

The nematodes described above belong to the Strongyloidea, based on the presence of a well developed, sclerotized buccal capsule and a copulatory bursa in the male, while the presence of four branches to the dorsal ray and a cylindrical buccal capsule place them in the family Cloacinidae. The externo-dorsal ray arising close to the lateral trunk, places the species within the sub-family Cloacininae, a sub-family restricted to the stomachs and oesophagi of macropodid marsupials (Lichtenfels 1980). Within the sub-family Cloacininae, six tribes are currently recognized (Beveridge 1987). The presence of a simple, elongate oesophagus lacking obvious division into corpus, isthmus and bulb, together with bipartite submedian cephalic papillae, places the species in the tribe Cloacininea, which currently contains three genera, the large genus *Cloacina* von Linstow, 1898, and the monotypic genera *Arundelia* Mawson, 1977 and *Beveridgea* Mawson, 1980. The species described here differs from *Cloacina* and *Arundelia* in having a relatively deep buccal capsule. In *Beveridgea*, the buccal capsule is longer than wide and is armed internally with teeth (Mawson 1980), which are lacking in the species described above. In addition, the species described here differs from all other genera in the tribe in having the anterior intestinal cells forming paired elongate extensions on either side of the oesophageal bulb. This character occurs in other tribes of the Cloacininae, such as in the Pharyngostrongylinea Popova, 1952 in the genera *Pharyngostrongylus* Yorke & Maplestone, 1926 and *Dorcopsistrongylus* Smales, 1982 and has been utilised as a character of generic significance (Beveridge 1982; Smales 1982). Analogous specializations of the anterior intestinal cells have been reported in the tribe Macropostrongylinea, in the genera *Alocostoma* Mawson, 1977, *Macropostrongylus* Yorke & Maplestone, 1926 and *Trigonostonema* Beveridge, 1981 (Beveridge 1981, 1985, 1986), as well as in tribe Zoniolaiminea in the genus *Cassunema* Beveridge & Johnson, 1981. In the tribe Labiostrongylinea, similar structures form distinctive diverticula between the oesophagus and intestine (Smales 1994, 1995). However, in all of these instances, although the anterior intestinal cells are enlarged, they do not extend anteriorly to envelop the oesophageal bulb. The structures seen in the species described here thus appear to be analogous to those found in the Pharyngostrongylinea, but are described for the first time in the Cloacininea. Since the species described here is clearly different from the three genera currently known within the Cloacininea, a new genus has been created to accommodate it.

The material described comes from two closely related species of scrub wallaby belonging to the genus *Dorcopsis*. The single specimen in BMNH has associated with it the host name *Dorcopsis veterum* (Lesson & Garnot, 1826). Groves & Flannery (1989) considered this name a *nomen dubium* and indicated that the only species of *Dorcopsis* occurring in the Port Moresby region, the locality of the present collection, was *D. luctuosa*. Consequently, the host name utilised here is that of *D. luctuosa* rather than the "*D. veterum*" of the label.

The finding of a new genus of cloacinine nematode in scrub wallabies from Papua New Guinea is not surprising given the limited extent to which the parasite fauna of New Guinea macropodids has been investigated and suggests that more detailed studies will uncover additional novel cloacinine genera.


## Acknowledgments

Thanks are due to T. Reardon, South Australian Museum for collecting the material from *D. hageni* and making it available for study and to I. Owen, Port Moresby, for collecting the material from *D. luctuosa*. R. Harrigan is thanked for excellent technical assistance and E. Harris for the loan of material from the Natural History Museum, London.

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# PRATYLENCHUS AND RADOPHOLUS SPECIES IN AGRICULTURAL SOILS AND NATIVE VEGETATION IN SOUTHERN AUSTRALIA

*BY IAN T. RILEY* & WIM. M. WOUTS†*

**Summary**

Riley, I. T. & Wouts, W. M. (2001) Pratylenchus and Radopholus species in agricultural soils and native vegetation in southern Australia. Trans. R. Soc. S. Aust. 125(2), 147-153, 30 November, 2001.
Pratylenchus species were found in 105 and Radopholus species in five of 284 samples taken from agricultural soils and native vegetation in areas of southern Australia. Pratylenchus crenatus (2 samples), P. neglectus (80), P. penetrans (3), P. scribneri (1), P. teres (10), P. thornei (13), Radopholus nativus (4) and R. crenatus (1) were identified. Pratylenchus teres has not previously been recorded in Australia and its widespread occurrence in agricultural soils in Western Australia may have important implications for crop production. Morphometrics and diagnostic features for P. teres are presented to facilitate its distinction from the morphologically similar P. thornei.
Key Words: Nematoda, Pratylenchus, Radopholus, distribution, species diversity, Pratylenchus teres.

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# *PRATYLENCHUS* AND *RADOPHOLUS* SPECIES IN AGRICULTURAL SOILS AND NATIVE VEGETATION IN SOUTHERN AUSTRALIA

by IAN T. RILEY[*] & WIM. M. WOUTS[†]

## Summary

RILEY, I. T. & WOUTS, W. M. (2001) *Pratylenchus* and *Radopholus* species in agricultural soils and native vegetation in southern Australia. *Trans. R. Soc. S. Aust.* **125**(2), 147-153, 30 November, 2001.

*Pratylenchus* species were found in 105 and *Radopholus* species in five of 284 samples taken from agricultural soils and native vegetation in areas of southern Australia. *Pratylenchus crenatus* (2 samples), *P. neglectus* (80), *P. penetrans* (3), *P. scribneri* (1), *P. teres* (10), *P. thornei* (13), *Radopholus nativus* (4) and *R. crenatus* (1) were identified. *Pratylenchus teres* has not previously been recorded in Australia and its widespread occurrence in agricultural soils in Western Australia may have important implications for crop production. Morphometrics and diagnostic features for *P. teres* are presented to facilitate its distinction from the morphologically similar *P. thornei*.

KEY WORDS: Nematoda, *Pratylenchus*, *Radopholus*, distribution, species diversity, *Pratylenchus teres*.

## Introduction

*Pratylenchus* Filipjev, 1936 consists of migratory endoparasitic nematodes that feed in the roots of plants and are important pests of dryland agriculture in southern Australia. *Pratylenchus neglectus* (Rensch, 1924) Filipjev & Schuurmans Stekhoven, 1941 and *P. thornei* Sher & Allen, 1953 have been identified as important pest species in south-eastern Australia and have been the subject of much research since the late 1980s (Vanstone 1991[1]; Taheri *et al.* 1994; Farsi *et al.* 1995; Potter *et al.* 1998; Vanstone *et al.* 1998; Nicol *et al.* 1999; Taylor *et al.* 1999; Hollaway *et al.* 2000). In response to the findings of this research, interest developed in determining the significance of *Pratylenchus* in Western Australia (WA). This prompted an extensive survey of the wheat growing areas of that State (Riley & Kelly in press). This survey revealed that potentially yield-limiting populations of *P. neglectus* and *P. thornei* occurred in much of the WA wheatbelt. In addition, the study found an unexpectedly high level of *Pratylenchus* species diversity. Although *P. neglectus* was most commonly detected, populations identified as *P. brachyurus* (Godfrey, 1929) Filipjev & Schuurmans Stekhoven, 1941, *P. penetrans* (Cobb, 1917) Filipjev & Schuurmans Stekhoven, 1941, *P. scribneri* Steiner in Sherbakoff & Stanley, 1943, *P. thornei*, *P. zeae* Graham, 1951 and an undescribed species similar to *P. thornei* were also found. Concurrently with this survey, *Radopholus nativus* Sher, 1986 was found in 10 of 300 diagnostic samples with migratory endoparasitic nematodes (Riley & Kelly 2001), further highlighting the diversity of migratory endoparasites in cropping areas of WA.

The species diversity in WA has significant ramifications because, until now, all efforts to establish resistance of crop species and cultivars grown in southern Australia have been limited to *P. neglectus* and *P. thornei* (Taylor *et al.* 2000; Hollaway *et al.* 2000). Also DNA based quantification of root lesion nematodes in cropping soils, provided initially by the South Australian Research and Development Institute (SARDI) and now by C-Qnetec Diagnostics (a division of Aventis CropScience) is restricted to *P. neglectus* and *P. thornei*. The work of Taylor, Hollaway and their coworkers has already shown that resistance to either *P. neglectus* or *P. thornei* does not always provide resistance to the other (Taylor *et al.* 2000; Hollaway *et al.* 2000). This means that successful management of *P. neglectus* and *P. thornei* could be undermined by a shift to predominance of other *Pratylenchus* species for which the crops grown are not resistant. It is, therefore, important that in population monitoring all *Pratylenchus* species occurring in cultivated fields and native vegetation in agricultural areas are identified, either by conventional diagnosis or DNA tests, so that effective options can be determined for sustainable management.

Taxonomists examined only a limited quantity of material from the earlier survey in WA (Riley & Kelly in press). Combined with the limited number and nature of surveys for *Pratylenchus* in south-eastern Australia, this means that the diversity of species of *Pratylenchus* in southern Australia is largely unknown. For the present study soil and root samples were therefore collected in areas of southern

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[1] VANSTONE, V. A. (1991) The role of fungi and the root lesion nematode, *Pratylenchus neglectus*, in damaging wheat roots in South Australia. PhD thesis University of Adelaide (unpub.).

Australia for the extraction of *Pratylenchus* spp. and their identification by detailed morphological examination and morphometrical comparison, and to provide additional information on geographical distribution. The results are presented and discussed below.

## Materials and Methods

Soil and root samples were obtained in dryland cropping areas of the southern States of mainland Australia in September and October, 1999. In South Australia (SA), 173 samples were collected from 49 sites and in WA, 102 samples from 38 sites. Sites were generally cultivated fields with adjacent native vegetation. Thirty five per cent of the samples from SA and 48% from WA were collected from cultivated fields. Samples from cultivated soils were composites of about six subsamples of roots and soil to 100 mm deep and samples from native vegetation were mostly collected adjacent to single plants. Sites in SA were selected along public access routes providing reasonable coverage of the main wheat growing regions viz., Murray Mallee, Mid North, Yorke Peninsula and Eyre Peninsula. In WA, a proportion of the sites visited had been identified previously as potentially having species other than *P. neglectus* and *P. thornei*; other samples were collected in areas where the greatest species diversity was known to occur. A further nine samples from eight sites from cropping areas in Victoria (Vic.) were provided by G. Hollaway (Agriculture Vic.).

Nematodes were extracted from soil by wet sieving (45 μm) and sugar flotation (Wouts & Sher 1971) and from roots in a misting cabinet (Southey 1986). Nematodes were heat killed, fixed in formalin and mounted in glycerol for microscopic examination (Wouts & Sher 1971).

## Results

*Pratylenchus* species were found in 105 samples and included *P. crenatus* Loof, 1960, *P. neglectus*, *P. penetrans*, *P. scribneri*, *P. teres* Khan & Singh, 1975 and *P. thornei* (Table 1). Some populations could not be identified to species level because of lack of adults or obscured characters. Although some *Pratylenchus* species were found in native vegetation, most were present in cultivated soils associated with field crops, pasture or weeds. In SA, where native vegetation was more thoroughly sampled, three of the four species collected were also found in these less disturbed habitats.

*Pratylenchus crenatus* was found in only two samples both from wheat fields near Westmere and Willaura, Vic. These localities are in a 600-700 mm rainfall zone, a zone not sampled in WA and SA.

*Pratylenchus neglectus* was the most common species in SA, being found in 95% of the *Pratylenchus* populations sampled in that State. Although *P. neglectus* is considered to be the most common species in cropping areas of WA (Riley & Kelly in press), our sampling purposefully focused on areas where this species was known to be less common, so *P. neglectus* was found in only 30% of *Pratylenchus* populations sampled in WA. *Pratylenchus neglectus* was found in most crops including some that are considered poor or non hosts viz., field pea, lupin and vetch (Taylor *et al.* 2000). *Pratylenchus neglectus* was also found in Vic.

*Pratylenchus penetrans* was found in native vegetation at one site in SA and in a narrow-leafed lupin crop (*Lupinus angustifolius* L.) and associated weedy brassica in WA.

*Pratylenchus scribneri* was found in only one sample of barley roots from SA, but there were few specimens and the identification is somewhat uncertain.

*Pratylenchus teres* was found only in WA where it was the most common of the species collected (40% of populations). It was found in association with a broad range of plant species viz., canola, native plants, oat, pasture plants, various weeds and wheat. Given that this is a new record for Australia, measurements are provided (Table 2) for comparison with earlier descriptions and diagrams to show (Fig. 1) some difference from *P. thornei*, the species it most closely resembles.

*Pratylenchus thornei* was found in the three States, mostly in cropping soils but also in native vegetation in SA. Notably, it was collected in association with field pea and lentil, both crops considered to be resistant (Hollaway *et al.* 2000). This may represent carryover from the previous season. *Pratylenchus thornei* was found in a relatively minor proportion (7%) of *Pratylenchus* populations in SA, where samples were collected more randomly. In WA, about 24% of samples had *P. thornei* but this is likely to reflect the different sampling criteria.

Mixed populations of *P. neglectus* and *P. thornei* were found in 6 samples (4 sites) from SA and 2 samples from WA. Therefore more than half the *P. thornei* populations detected occurred in conjunction with *P. neglectus*. Apart from the uncertain record of *P. scribneri*, which was associated with *P. neglectus*, none of the other species was found in mixed populations.

*Heterodera avenae* Wollenweber, 1924 males were also extracted from wheat and barley root systems from 12 sites in SA. In all cases, they occurred in association with *P. neglectus* and in one case with a mixed population of *P. neglectus* and *P. thornei*. *Heterodera avenae* was not found in WA. This is consistent with the finding of Riley & Kelly (in

TABLE 1. *Species of* Pratylenchus *found in association with crops, pasture, weeds and native vegetation in southern states of mainland Australia, indicating the number of samples and associated plants for each species.*

| *Pratylenchus* species | Australian State | | | | | |
|---|---|---|---|---|---|---|
| | South Australia | | Western Australia | | Victoria | |
| | Samples | Plants | Samples | Plants | Samples | Plants |
| *P. crenatus* | 0 | | 0 | | 2 | wheat |
| *P. neglectus* | 71 | barley, canola, lupin, native, oat, pea, vetch, wheat | 8 | mixed pasture, oat, weeds, wheat | 1 | wheat |
| *P. penetrans* | 1 | native | 2 | lupin, weedy brassica | 0 | |
| *P. scribneri* | ?1[2] | barley | 0 | | 0 | |
| *P. teres* | 0 | | 10 | canola, native, oat, pasture, weeds, wheat | 0 | |
| *P. thornei* | 5 | native, pea, wheat | 6 | lupin, oat, wheat, weedy brassica | 2 | lentil, wheat |
| *Pratylenchus* sp. | 3 | native, vetch | 2 | wheat, weeds | 0 | |
| Total samples with *Praylenchus*[1] | 75 | | 25 | | 5 | |

Populations of mixed *Pratylenchus* spp. were found in some samples. [2]Identity uncertain.

TABLE 2. *Morphometrics of* Pratylenchus teres. (Measurements in µm).

| | Western Australia | Khan & Singh, 1975 | | | van den Berg & Quénéhervé 2000 |
|---|---|---|---|---|---|
| | | Paratypes | Amritsar | Solan | |
| | n = 10 | n = 5 | n = 17 | n = 4 | n = 8 |
| | Mean ± SD (Range) | Mean (Range) | Mean (Range) | Mean (Range) | Mean ± SD (Range) |
| Total length (L) | 580 ± 40 (490-620) | 410 (400-420) | 550 (420-630) | 550 (520-600) | 504 ± 18.2 (472-531) |
| Width of body | 25 ± 1.9 (21-28) | - | - | - | 18. 17 |
| Length of stylet | 16.6 ± 0.54 (15.5-17.0) | 17 (17-18) | 16 (16-18) | 17 (17-18) | 18 ± 0.4 (17-18) |
| Height of stylet base | 2.2 ± 0.23 (2.0-2.5) | - | - | - | 2 |
| Width of stylet base | 4.6 ± 0.44 (4.0-5.5) | | - | - | 3.2 |
| Width of first body annule | 9.7 ± 0.46 (9.0-10.5) | - | - | - | - |
| Distance of dorsal gland opening from stylet base | 2.8 ± 0.51 (2.0-3.5) | - | | | 3 |
| Length of oesophagus | 86 ± 6.6 (79-98) | - | | - | |
| Distance of secretory-excretory pore from anterior end | 89 ± 4.5 (79-95) | | - | | 84. 85 |
| Distance the oesophageal glands overlap the intestine | 44 ± 20.4 (11-73) | - | | - | |
| Length of posterior uterine branch | 18.6 ± 3.3 (14-24) | - | - | - | 36 ± 7.5 (33-40) |
| Length of tail | 38 ± 2.4 (34-42) | - | - | - | 34.5 ± 2.8 (31-39) |
| Length of the clear part of the tail | 4 ± 0.7 (3-5) | | - | - | |
| Body width at the position of the vulva | 23 ± 1.8 (20-26) | - | | - | - |
| Body width at the position of the anus | 16 ± 1.5 (14-18) | | - | | - |
| a | 24 ± 2.6 (21-30) | 21.7 (21.1-23.3) | 30.8 (22.1-39.9) | 29.5 (28.8-30.7) | 30 ± 0.9 (29-31) |
| b | 6.8 ± 0.46 (6.2-7.4) | 4.1 (4.1-4.2) | 4.6 (3.5-5.6) | 4.6 (3.9-5.5) | 4 |
| c | 15.5 ± 1.29 (12.2-16.7) | 14 (14-16) | 18.2 (11.5-27.0) | 16.5 (14.8-17.9) | 14.5 ± 1 (13-16) |
| c' | 2.4 ± 0.24 (2.1-2.9) | - | - | - | 3 |
| V | 74 ± 2.2 (68-76) | 73 (70-77) | 70 (69-78) | 73 (72-75) | 72 ± 2 (69-74) |

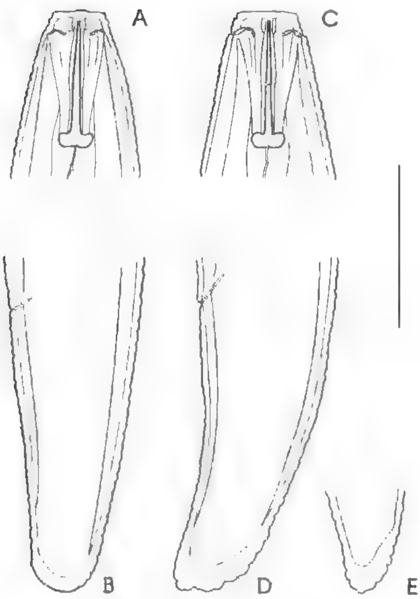


Fig. 1. A, B. *Pratylenchus thornei*. A. Anterior end. B Posterior end. C-E. *Pratylenchus teres*. C. Anterior end. D. Posterior end. E. Tail terminus variation. Scale bar = 20 µm.

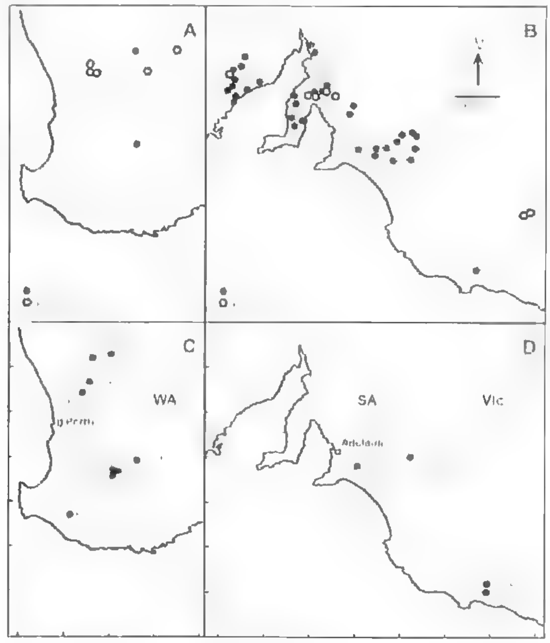


Fig. 2. Distribution of *Pratylenchus* and *Radopholus* species collected in southern Australia. A, B. *Pratylenchus neglectus* and *Pratylenchus thornei*. A. In WA. B. In SA and Vic. C, D. Other species. C. In WA. D. In SA and Vic.

press) that *H. avenae* is not common in that State.

*Radopholus nativus* and *Radopholus crenatus* Colbran, 1971 were found in native vegetation; two samples each of *R. nativus* in SA and WA and one sample of *R. crenatus* in WA. One *R. nativus* population from SA occurred in association with *P. neglectus*. Although *R. nativus* was not found in cropping soils, as reported by Riley & Kelly (2001), a small number of *Radopholus* juveniles was found at the same site near Wyalkatchem that they had investigated. This site was dominated by capeweed (*Arctotheca calendula* (L.) Levyns) and a small proportion of grasses (such as *Lolium rigidum* Gaudin, *Hordeum leporinum* Link and *Bromus* sp.) in 1999. It appears that capeweed and these grasses are not hosts for either *P. neglectus* nor *R. nativus*, which were absent or scarce in the eleven samples collected at the site. This observation is consistent with the findings of Vanstone & Russ (2001a, b), who have shown the plants species found at this site to be largely resistant to *P. neglectus*.

Figure 2 shows the geographic distribution of the *Pratylenchus* spp. and *Radopholus* spp. collected. In WA, species other than *P. neglectus* occurred toward the west and south where annual rainfall is higher. In SA and Vic., *P. neglectus* was widespread and, although less common, *P. thornei* occurred throughout most of the area sampled. The other species present in eastern SA were mostly in native vegetation. *Pratylenchus crenatus* occurred in cropping soils of a high rainfall area of Vic.

## Discussion

This study confirms the diversity of *Pratylenchus* species in WA cropping soils (Riley & Kelly in press) and the relative lack of diversity in SA (Nicol 1996[1]). A predominance of *P. neglectus* and/or *P. thornei* in cereal soils is consistent with that in other countries with climates similar to southern Australia, for example South Africa (Jordaan *et al.* 1992) and Italy (Palmisano 1992). In Portugal, however, *P. penetrans* and *P. crenatus* were more common in cereals and other crops than *P. neglectus* and *P. thornei* (de O. Abrantes 1987). Similarly, in other climatic zones, other *Pratylenchus* species have become predominant in cereal crops, for example *P. scribneri* is predominant in Arkansas, USA (Robbins *et al.* 1989) and *P. penetrans* in Prince Edward Island, Canada (Kimpinski *et al.* 1989).

While *P. neglectus* and *P. thornei* may be the most common species in cereal producing areas of

[1] Nicol, J. M. (1996) The distribution, pathogenicity and population dynamics of *Pratylenchus thornei* on wheat in South Australia. PhD thesis University of Adelaide (unpub.)

Australia and similar areas worldwide, some authors report wide species diversity as seen in WA. For instance, Jordaan *et al.* (1992) found *P. brachyurus*, *P. penetrans* and *P. zeae* along with *P. neglectus* and *P. thornei* in wheat fields in winter rainfall areas in South Africa and Potter & Townshend (1973) found *P. crenatus*, *P. neglectus* (most common), *P. penetrans* and *P. pratensis* (de Man, 1880) Filipjev 1936 in cereal soils in Ontario, Canada. In moister, more agriculturally diverse environments species diversity can be even greater: nine species were reported from field soils of eastern Germany (Decker & Dowe 1974) and 14 species in eastern Canada (Townshend *et al.* 1978).

*Pratylenchus teres* has not previously been recorded in Australia. However, in the earlier survey of WA, Riley & Kelly (in press) found an unidentified species similar to *P. thornei* with affinities to *P. teres* or *P. fallax* (M. Hodda, pers. comm., 1998), which was probably the *P. teres* as identified in this study. *Pratylenchus teres* identified here closely fits the original description of the species (Khan & Singh 1975) and material from the French West Indies recently described by van den Berg and Quénéhervé (2000) (Table 2). The WA specimens seem to be somewhat longer, but fit within the range for the stylet length and the a and c values. The b value is considerably higher (6.2-7.4 v. 4.1-5.5) but this may be due to distortion of the oesophageal region in several of our specimens which may have moved the base of the oesophagus somewhat anteriad resulting in measuring inaccuracies. The greatest discrepancy seems to be the length of the posterior uterine sac which in the original description as well as by van den Berg and Quénéhervé, is reported as about twice as long as in our material. *Pratylenchus teres* closely resembles *P. thornei* in body, stylet and tail length, the shape of the lip region and the stylet knobs and the position of the vulva (Fig. 1). *Pratylenchus teres*, therefore, could be confused with *P. thornei*, especially in areas where the latter is common. The annulated tail, the main character separating the two species, is quite variable and specimens with only a light crenation on the tail could be identified as *P. thornei* with slight markings on the tail terminus, a characteristic not uncommon in that species. Generally though when material is plentiful, the difference between the two species is obvious with *P. teres* having a more pointed crenate tail. It was further observed that the lip region of *P. teres* is about one micron wider than the lip region of *P. thornei*. This character may be difficult to measure but in direct comparison is immediately apparent. Also the lip region of *P. teres* is more set off and the cephalic framework extension shorter than in *P. thornei*.

Although not all the species previously found in dryland cropping soils of WA (Riley & Kelly in press) were collected, the addition of *P. teres* to the list is significant. As *P. teres* was the most common species collected in WA and occurred in a variety of crops and native vegetation, it should be given priority for further investigation. As indicated above, work on *Pratylenchus* in southern Australia has concentrated on *P. neglectus* and *P. thornei* with differences in host range, distribution and impact being found. It is likely that *P. teres* will differ from both of these and crop management strategies designed to control *P. neglectus* and *P. thornei* may be undermined by *P. teres*. Since its description from mustard in 1975 there have been relatively few reports of *P. teres* and studies of its biology or agricultural significance. There is, therefore, no information from which to predict its importance in WA.

The detection of *P. penetrans* in WA is notable because the lupin roots were exceptionally heavily infested at this site and the preceding wheat crop had also been heavily infested (S. Kelly, pers. comm. 2000). Narrow leafed lupin is considered to be resistant to *P. neglectus* (V. Vanstone, pers. comm. 2000), the only lupin/*Pratylenchus* combination assessed, so it appears that this resistance is not general for all *Pratylenchus* spp. The occurrence of *P. penetrans* in lupin, wheat and brassicas is also important as it indicates that it may not be easily controlled by crop rotation (especially if its host range includes the common cereal, legume and brassica crops). *Pratylenchus penetrans* has been recorded widely in all Australian States, largely in higher rainfall areas and/or associated with perennial crops (McLeod *et al.* 1994) but also in association with lupin in Queensland (Qld) and brassicas in various States.

*Pratylenchus scribneri* has been identified recently in samples from cropping soil in WA (Riley & Kelly in press), but earlier records in Australia are now considered to be *Pratylenchus jordanensis* Hashim, 1984 (McLeod *et al.* 1994). Further collections of *P. scribneri* in Australia are required to confirm its presence.

*Pratylenchus crenatus* was found only in a high rainfall area of Victoria, which lies outside the main cropping areas of southern Australia. It has been recorded in other Australian States in high rainfall areas and mostly in association with perennials (McLeod *et al.*, 1994). With the marked increase in annual cropping associated with the relative decline in returns from grazing enterprises in such areas, it is possible that *P. crenatus*, along with other *Pratylenchus* species, will emerge as important pests.

The collection of *R. nativus* from native vegetation in SA is also noteworthy. This species has been recognised as a potential agricultural pest in WA and, although less common than some *Pratylenchus* spp., it is found widely distributed (Riley & Kelly 2001). If particular factors, such as high frequency of lupin cropping, are confirmed to contribute to the dominance of *R. nativus* over *Pratylenchus* under certain circumstance in WA, a search based on this information may also find *R. nativus* in agricultural soils in SA.

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# THE USE OF DIPROTODON AS A BIOSTRATIGRAPHIC MARKER OF THE PLEISTOCENE

*BRIEF COMMUNICATION*


### Summary

Diprotodons are the largest marsupials ever to have lived with individual masses of some animals estimated to have reached up to two tonnes[1]. They are amongst the most common animals identified in palaeontological literature with more than 240 citations[2]. Although seven different species have been described in the genus Diprotodon, most workers contend that there are probably only two or three valid taxa[1]. All Diprotodon species have been assumed to be Pleistocene-Recent in age[3]. As a result they have been used as biostratigraphic markers for various fossil sites that lack firm dates[4,5]. There are several reports in the literature however, that suggest the presence of Diprotodon in Pliocene deposits[6,7,8]. This note reassesses two Diprotodon specimens recorded from the Pliocene Chinchilla Sand in light of their preservation and historical collection data. It also examines other Pliocene records for the genus and concludes that Diprotodon is still a valid marker of the Pleistocene.

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BRIEF COMMUNICATION

# THE USE OF *DIPROTODON* AS A BIOSTRATIGRAPHIC MARKER OF THE PLEISTOCENE

Diprotodons are the largest marsupials ever to have lived with individual masses of some animals estimated to have reached up to two tonnes[1]. They are amongst the most common animals identified in palaeontological literature with more than 240 citations[2]. Although seven different species have been described in the genus *Diprotodon*, most workers contend that there are probably only two or three valid taxa[3]. All *Diprotodon* species have been assumed to be Pleistocene-Recent in age[3]. As a result they have been used as biostratigraphic markers for various fossil sites that lack firm dates[4,5]. There are several reports in the literature however, that suggest the presence of *Diprotodon* in Pliocene deposits[6,7]. This note reassesses two *Diprotodon* specimens recorded from the Pliocene Chinchilla Sand in light of their preservation and historical collection data. It also examines other Pliocene records for the genus and concludes that *Diprotodon* is still a valid marker of the Pleistocene.

The Chinchilla Sand is a sequence of weakly consolidated grey to yellowish and light brown sands, ferruginised heterogeneous conglomerates, grits, sandy clay and clays. These outcrops range from shallow beds to sections several metres deep[8]. A wide range of exclusively Pliocene taxa has been recovered from these sediments and are known as the Chinchilla Sand Local Fauna[8]. Two *Diprotodon* mandibles (QM F5280, QM F10293) have also been recorded as coming from the deposit but have no stratigraphic data associated with them. The locality "Chinchilla" on the registration label and the preservation of the mandibles have been used as the basis to justify that the fossils were collected from Pliocene horizons at Chinchilla[9]. If this were the case, then the validity of using *Diprotodon* as a biostratigraphic marker of the Pleistocene would be called into question.

Contrary to assertions that the Chinchilla Sand contains only Pliocene horizons[9] however, is evidence of superimposition of Quaternary alluvia on the Chinchilla Sand[10]. Interpretation of the provenance of any specimens collected from the Chinchilla locality should therefore proceed with caution unless confirmed by stratigraphic or biostratigraphic evidence. The situation is further complicated by less than perfect collecting data[11] with some specimens that are listed from Chinchilla having been collected from other areas on the Darling Downs[*]. The large mandibles are indeed specimens of *Diprotodon*. The label associated with one of the specimens simply lists 'Chinchilla' as the collecting locality, the collector as K. Broadbent and a collection date of 2 February 1887. Broadbent's field notes for the month of February reveal that his fossil collecting activities were in black soil on the banks of the Condamine, some distance from Chinchilla[**]. The description of the collecting locality is more consistent with Pleistocene sites such as Warra, just east of Chinchilla. Fossils collected by Broadbent from outlying sites were brought into Chinchilla and shipped back to the Queensland Museum. This may be how Chinchilla became listed as the collecting locality for the specimens.

In April of the same year, Broadbent collected the type specimens of *Euowenia grata* from the Chinchilla Sand[12]. The preservation of these specimens does not match that of either of the *Diprotodon* mandibles. Given the information from Broadbent's field diaries and the fact that both *Diprotodon* specimens do not match "traditional" Chinchilla Sand preservation, it is reasonable to suggest that *Diprotodon* does not form part of the Pliocene Chinchilla Local Fauna and that the two mandibles are from a different locality on the Darling Downs. Furthermore the presence of abundant specimens of the structurally ancestral *Euryzygoma dunense* in the Chinchilla Sand would also suggest that the *Diprotodon* mandibles did not come from these Pliocene horizons[11,13].

There are two other supposed records of *Diprotodon* from Pliocene localities. A record based only on a tooth fragment from Fisherman's Cliff Local Fauna[6] is now regarded as doubtful[14]. The presence of *Diprotodon* in the second, the Kanunka Local Fauna, is based on three worn incisors (a tip of a lower incisor: a left I and a right I)[7]. Given the variability of these teeth in diprotodontines it is reasonable to question their identification and suggest that they may in fact represent the remains of *Euryzygoma*. Pending more conclusive evidence of stratigraphically controlled specimens of *Diprotodon* from Pliocene deposits it is reasonable to assume that the genus is restricted to Quaternary deposits. As such, it is a useful biostratigraphic marker to assess the age of certain deposits. A better understanding of the biochronology of different diprotodontid species has the potential to resolve the age of various Plio-Pleistocene strata that fall outside traditional dating techniques or where datable material is not available.

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# OBITUARY

## JOAN BURTON PATON AM, BSc (Hons), MSc

## 1.ix.1916 – 28.iv.2000


### Summary

Joan Burton Paton died in Adelaide on 28 April, 2000, after an outstanding career as scientist and teacher. She was the fifth and youngest child of John and Dora Cleland. When her father was appointed to the Chair in Pathology at the University of Adelaide in 1920, the family moved to Adelaide and after a number of years took up residence in what is now regarded as the family home – 1 Dashwood Road, Beaumont, where Joan spent the rest of her life. Her schooling began at Miss Dutton's Kindergarten, Fullarton and than at Presbyterian Girls' College (now Seymour College). Joan began her science degree at the University of Adelaide in 1934 graduating BSc in 1937 followed by an Honours degree in Biochemistry in 1939 and an MSc in 1947. Her career as a Biochemist commenced at the Institute of Medical and Veterinary Science in 1940, where she worked for 12 years. She published the first of her many papers in the South Australian Ornithologist in 1939 and this was followed by contributions to the South Australian Naturalist.

JOAN BURTON PATON
AM, BSc(Hons), MSc

At Coolgubbin Camp, Connie Sue Highway, Great Victoria Desert, June 1974.
Photograph courtesy of Mrs A. Hardy

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In 1951 Joan married Pat Paton and with him was a director of an engineering firm making scientific equipment. The demands of marriage, children and caring for an elderly father were all taken in her stride. She inspired many people to study natural science as a hobby and taught them to understand the complexities of the environment and its conservation, particularly through the Workers Education Association and the Department of Continuing Education at the University of Adelaide. It was during the 1990s that I became better acquainted with Joan. She would frequently visit Pat Thomas in the South Australian Museum at lunch time and sometimes the three of us would eat together in Pat's laboratory where a plentiful supply of sweet vermouth was kept. This Pat served to us in beakers and, even though we knew that the same beakers had contained a kangaroo's liver or salmon's gut only minutes before, we appreciated the generosity and the purifying effects of alcohol! It was here that we heard Joan describe how to manage wildlife sensibly. She was a great conservationist and accepted the gun as a management tool. Joan was a worker, a helper and a born leader.

After talking with Joan's friends, I compiled a little about her personal life. This follows.

**Dean Cordes**, Department for Environment and Heritage: Joan contributed a long period of voluntary service to National Parks and Wildlife, SA. She was appointed a member of the National Parks Commission from 1969 to 1972. With the winding up of the Commission, she was appointed to National Parks and Wildlife Advisory Committee from 1972 to 1979. In 1980, the Minister for the Environment appointed Joan as a founding member of the Sturt Consultative Committee on which she served until her death.

**Russell Thomas**, Leabrook: Her love of things ornithological was paramount. As a teacher she displayed great patience to students of all ages. She was a true leader - she had knowledge and drive.

**Barbara Hardy AO**, Seacliff: Joan was quiet and humble but lots of fun to be with in the Australian Bush. On our first camping trip, Rex Ellis had in his vehicle, a small refrigerator stacked with beer but when Joan collected a rare bird species, out went the beer and in went the bird carcasses—no questions. Joan had a great understanding of nature and its conservation needs and she was an effective lobbyist for better management of the natural environment.

**Hans Mincham**: I served as Information Officer at the South Australian Museum for twelve years from 1964. During that time, Joan Paton was my source of information for answering questions on Ornithological matters from the public. She fought strongly to save native habitat.

**Anne Dow**, Medindie: My family and I accompanied Joan on several expeditions. Joan was brilliant, talented, dedicated to Ornithology with a great sense of humour.

**Enid Robertson**, Blackwood: "The birds are where the plants are" so said Joan on the first of our many shared camping trips. We shared sleeping quarters in many unorthodox places: Kakadu, a school-room in Meningie and we shared many strange bedfollows like cane toads near Mount Isa and mosquitoes, which had not learned the rules about being put off by insect repellant, at Fogg Dam.

**Margaret Ker**, Colonel Light Gardens: I first met Joan at her bird classes in 1968. Impressed upon me was – whenever I came across a freshly killed bird by the roadside, it was to be picked up, frozen and handed on to Joan. I attended many Consultative Committee meetings in the country with Joan and she was a delight to be with.

**Lee Parkin AO**, Leabrook: Joan leaves a legacy of dedicated bird-watchers whose lives are enriched by Joan's infectious love of these beautiful creatures. In all her many involvements she was always conscientious, hard working and confident in her approach to conservation matters. She often presented me with gigantic pears, Jerusalem artichokes and /or duck eggs from her rambling historic garden. She was much loved and admired by all who knew her.

**Barry Hutchins OAM**, Northfield: Joan was past President and Life Member of the Adelaide Ornithologists Club Inc. and she maintained a strong interest in club activities until her death. She was always keen to debate conservation issues and published her opinions. Conservation in South Australia benefited greatly from her help.

**Muriel Reid, Hackney**: I first encountered Joan on the hockey field when we played for University teams and later as a student at Joan's WEA class for beginners in Ornithology. Joan and I were members of the Tatler's Club. Here her papers and short witty poems were well received. Her memory for reciting poetry, learned as a child, was legendary.

**Ross Reid**, Hackney: My memories of this wonderful woman began at the Institute of Medical and Veterinary Science where she was a clinical biochemist and I was a second year medical student but it was her lectures on Ornithology which kindled my continuing interest in bird-watching. On our expeditions, she always had her students up and about at first light "at the best part of the day", irrespective of the weather. "Record those observations" she would say. She was an accurate observer and a leader in biological conservation.

Joan attended meetings of the South Australian Ornithological Association with her father when she was a student at Presbyterian Girls' College, Glen Osmond (now Seymour College). She helped her father by skinning birds and even displayed some of these specimens at a meeting of the Association in 1932. It was in that year too, that she was presented with a pair of canaries and a sum of money for winning an essay competition on birds she had seen during her holidays. It was during this period that her life-long interest in birds was kindled.

Joan was also a keen sportswoman, gaining a University Blue for Hockey and playing in the State Hockey team. A team mate described her as "gritty and determined", qualities that prevailed in every endeavour throughout her life.

Throughout her child-rearing years Joan did not give up work and in 1953 with two babies still at breast she continued teaching at the University of Adelaide. It was commonly accepted that she managed to feed the twins, knit and read all at the same time. She was part-time tutor and demonstrator in Biochemistry and then in Biology and did not retire until 1987, 34 years later. She juggled her life marvellously during these periods and when required, as rumour would have it, locked the children in the tennis court, rushed off to the University and asked Pat, her father or the dog to keep an eye on them. When challenged about this she replied sternly with gritted teeth : "It did them no harm".

From 1944, Joan was a part-time lecturer with the WEA giving courses on nutrition. In 1967 she started what became her greatest passion – teaching ornithology - something that she continued until 1999.

Sir John Cleland, her father, used to fill the family house with plant specimens and fungi. Joan, on the other hand, would litter the verandahs and attic with skeletons and wings of birds carefully pinned out to show diagnostic features. Useful remains such as the stomachs and intestines were saved and dispatched to Pat Thomas to be examined for parasites. And, maintaining the family tradition, several parasites were subsequently named after Joan - an honour she shared with her father.

Joan Paton became increasingly involved in the bird clubs of the State and Nation, serving as a Vice President and then as President from 1979-1982 of the South Australian Ornithological Association. She was the Regional Representative of the Royal Australasian Ornithologists' Union from 1973-1977 before joining the Council of the RAOU from 1982-1987 and also served as Vice President and then President of the Adelaide Ornithologists' Club from 1991-1993. And, on top of this, she spent 17 years on the School Council of the Presbyterian Girls College (now Seymour College), regularly attended meetings of the Royal Society of South Australia, Royal Geographical Society of South Australia and Medical Sciences Club, wrote chapters for books on the Birds of the Heysen Trail, the Flinders Ranges, the early history of Encounter Bay and many scientific papers on South Australian birds. She was also an Honorary Research Associate at the South Australian Museum for 25 years.

These collective contributions to ornithology, education and conservation were recognised when Joan became a Member of the Order of Australia

(AM) in 1996. Her greatest contribution and greatest asset were her ability to teach, enthuse, encourage and inspire others. She had great patience - never losing her temper, never responding abruptly, always trying to aid that person's learning and enjoyment. She treated all people as equals, never fussed over anyone, and never expected anything in return. She did herself and her family proud and touched and moulded the lives of her children. A generation of science students and doctors fondly recalls her teaching them biochemistry.

Joan was the author of Pearson Island Expedition 1969. Birds. *Transactions of the Royal Society of South Australia* **95**, 149-153.

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