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BY RUSSELL J. SHIEL & WALTER KOSTE

Summary

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NEW SPECIES AND NEW RECORDS OF ROTIFERA (ASCHELMINTHES) FROM AUSTRALIAN WATERS

by Russell J. Shiel* & Walter Koste†

Summary

Shiel, R. J. & Koste, W. (1985) New species and new records of Rotifera (Aschelminthes) from Australian waters. *Trans. R. Soc. S. Aust.* 109(1), 1-15, 28 June, 1985.

One hundred and sixty-seven taxa are added to the Rotifera recorded from Australian waters, bringing the total to over 600. New taxa described and figured are: *Lepadella patella* var. nov., *Lecane tasmaniensis* sp. nov., *L. unguitata* var. nov., *Asplanchna brightwelli asymmetrica* ssp. nov., and *Testudinella husseyi* sp. nov. In addition, *Hexarthra oxyuris* (Sernov) is redescribed and figured and its synonymy discussed.

KEY WORDS: Rotifera, new species, new records, Australia.

Introduction

Although knowledge of the systematics and ecology of Australian Rotifera has improved considerably in recent years, it remains fragmentary. Preliminary taxonomic works (Shiel & Koste 1979, Koste & Shiel 1980a, b) stemmed from a study of the zooplankton of the Murray-Darling basin, from samples collected along the Magela Creek, Northern Territory (Koste 1981, Koste & Shiel 1983, Tait *et al.* 1984) and in southwest Western Australia (Brock & Shiel 1983, Koste *et al.* 1983). The rotifer fauna of most of Australia remains unstudied. While this can be attributed in part to a shortage of 'rotiferologists' rather than of rotifers (cf. Dumont 1983), there are undoubtedly more collectors of zooplankton in Australia than the rotifer records indicate. Systematic difficulties appear to be a major obstacle.

We noted earlier (Koste & Shiel 1980a) that major systematic works deal with the northern hemisphere fauna; there is limited information on the Rotifera of the southern continents. Indeed, a global revision of the Class is desirable, particularly since the recognition of ecotypic variation in response to habitat variability. In the brachionids, for example, extensive intraspecific variation in size, lorica morphology or spine length has been demonstrated in response to habitat temperature, pH, salinity or predators, (e.g. Gilbert 1967, Green 1977, Gilbert & Stemberger 1984). This raises the difficulty of specific determination when the extent of intraspecific variability is not known for most rotifer genera, and accounts in part for the proliferation of "species" based on very limited material.

To help overcome taxonomic problems we commenced a comprehensive illustrated key to the planktonic monogonont Rotifera recorded from Australian waters. In view of complex rotifer assemblages, particularly in tropical Australia, we have found it necessary to extend the key to include facultatively or occasionally planktonic taxa, including Bdelloidea. The first diagnostic keys have been prepared (Koste & Shiel in press a,b), but an entire revision may take several years. Here we update the species list and describe new taxa from our (and other) collections.

In the first checklist, Shiel & Koste (1979) recorded 331 taxa, in 73 genera. A further 106 taxa were listed by Koste & Shiel (1980a). One of these, cited as *Filinia hoffmanni* (sic) (= *F. hofmanni* Koste, 1980), was an error; it is a European species. To the 436 known taxa we add here a further 167, collated from the literature since 1980, from material made available to us by others, and from our collections. An important contribution was made by Berzins (1982), who provided a list of rotifers identified from collections made in Australian waters over a period of 30 years. Many of these are first records for the continent, and a number of species are new. However several species described as new appear to be synonyms, artefacts of preservation or misidentifications. These are discussed in the text. Infrasubspecific taxa hitherto described as f. or var. are described in relation to the nominate ssp. simply to document variability, and are not named. More detailed ecological data and/or material will facilitate a later revision.

The format follows that of Koste & Shiel (1980b). All records are listed systematically following Donner (1965) for the Bdelloidea and Koste (1978b) for the Monogononta. Locally (or nearest named feature) and date of collection are given. Ranges of water quality are given where available. Published records are cited by author, unpublished records by collector. Only new taxa are figured. Types and paratypes are lodged with the South Australian Museum (SAM).

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SYSTEMATICS

Order BDELLOIDEA

Family Habrotrochidae

Habrotrocha bidens (Gosse), 1851
Loc: Bombala, N.S.W., in tree stump mould; 28.xii.1949, 8.i.1950.
Lit: Berzins (1982).

H. cucullata Murray, 1911
Loc: Bombala, N.S.W., creek moss; 8.i.1950.
Lit: Berzins (1982).

H. fusca (Bryce), 1894
Loc: Bombala, N.S.W., tree stump mould; 28.xii.1949.
Lit: Berzins (1982).

H. ligula Bryce, 1913
Loc: Bombala, N.S.W., tree stump mould; 28.xii.1949.
Lit: Berzins (1982).

H. microcephala (Murray), 1906
Loc: Melbourne, Vic.; moss and lichens; 1.ii.1951.
Lit: Berzins (1982).=*H. constricta* according to Donner (1965). The latter is known from N.S.W. (Murray 1911).

H. tranquilla Milne, 1916
Loc: Bombala, N.S.W., tree stump mould; 28.xii.1949.
Lit: Berzins (1982).

H. tripus (Murray), 1907
Loc: Yarra R., Ivanhoe, Vic., in terrestrial lichens; 1.i.1951.
Lit: Berzins (1982).

Family Philodinidae Bryce, 1910

Embata hamata (Murray), 1906
Loc: Yarra, R., McMahon's Creek, Vic.; 19.iii.1976.
Lit: Berzins (1982).

Dissotrocha hertzogi Hauer 1939
Loc: Hunter, R., near Gundy, N.S.W.; 11.xi.1953.
Lit: Berzins (1982).

Pleuretra brycei (Weber), 1898
Loc: Geraldton, W.A., moss/humus; undated, (?vi.1953).
Lit: Berzins (1982).

Macrotrachela aculeata (Milne), 1886
Loc: Bombala, N.S.W., tree stump mould; 28.xii.1949.
Lit: Berzins (1982).

M. angusta (Bryce), 1894
Loc: Bombala, N.S.W., tree stump mould; 28.xii.1949.
Lit: Berzins (1982).

M. concinna (Bryce), 1912
Loc: Geraldton, W.A., moss/humus; undated (?vi.1953).
Lit: Berzins (1982).

M. gunningi (Murray), 1911
Loc: Melbourne, Vic., moss/lichens; 1.ii.1951.
Lit: Berzins (1982).

M. nana (Bryce), 1912
Loc: Yarra R., Ivanhoe, Vic., moss/lichens; 1.i.1951, 1.ii.1951.
Lit: Berzins (1982).

M. smithi Milne, 1916
Loc: Bombala, N.S.W., moss; 8.i.1950.
Lit: Berzins (1982).

M. speciosa (Murray), 1907
Loc: Melbourne, Vic., moss/lichens; 1.ii.1951.
Lit: Berzins (1982).

Mniobia circinata (Murray), 1908
Loc: Melbourne, Vic., moss/lichens; 1.ii.1951.
Lit: Berzins (1982).

M. conarus Berzins, 1982
Loc: Heyington, Melbourne, Vic., moss/lichens: 14.i.1951.
Lit: Berzins (1982).

M. lineata Rahm, 1932
Loc: Heyington, and Yarra R., Ivanhoe, Vic., moss; 14.i.1951, 14.iii.1976.
Lit: Berzins (1982).

M. magna (Plate), 1889
Loc: Bombala, N.S.W., moss/lichens; 8.i.1950.
Lit: Berzins (1982).

M. ocypetes Berzins, 1982
Loc: Melbourne, Vic., moss/lichens; 1.ii.1951.
Lit: Berzins (1982).

M. scarlatina (Ehrenberg), 1853
Loc: Melbourne, Vic., moss/lichens; 1.ii.1951.
Lit: Berzins (1982).

Family Adenitidae Bryce, 1910

Adineta cuneata Milne, 1916
Loc: Bombala, N.S.W., tree stump mould; 26.xii.1949.
Lit: Berzins (1982).

Order PLOIMIDA Hudson & Gosse, 1886

Family Epiphanidae Bartos, 1959

Epiphanes macrourus (Barrois & Daday), 1894
Loc: Lake Grace-Kalgoorlie-Norseman area of southwest W.A.; viii.1978; x.1981.
Lit: Geddes *et al.* (1981), Koste *et al.* (1983).

Family Brachionidae Wesenberg-Lund, 1889

Brachionus caudatus personatus Ahlstrom, 1940
Loc: Winmurra Billabong, Magela Ck, near Jabiluka, N.T.; 15.iv.1980.
pH 5.44, 28.5°C, 6.2 mgl⁻¹ O_2, 23 μS cm⁻¹.
Lit: Koste (1981).

B. falcatus f. *reductus* Koste & Shiel, 1983
Loc: Winmurra Billabong, near Jabiluka, Magela Ck, N.T.; 4.xii.1980.
Lit: Koste & Shiel (1983).

B. kostei Shiel, 1983
Loc: Sheepwash Billabong, Yea, Vic.; 19.i.1982.
pH 7.0-7.7, 24°C, sat. O_2, <50-200 μS cm⁻¹, soft magnesium bicarbonate waters, high transparency (<1 NTU).
Lit: Shiel (1983).

B. pinneenaus Koste & Shiel, 1983
Loc: Cue, southwest W.A.; viii.1978.
Lit: Geddes *et al.* (1981).

B. quadridentatus ancylognathus (Schmarda), 1859
Loc: L. Bullenmerri, Vic.; 22.ix.1983.
Coll: I. J. Powling.

B. quadridentatus rhenanus (Lauterborn), 1893
Loc: L. Bullenmerri, Vic.; 22.ix.1983.
Coll: I. J. Powling.

B. quadridentatus minor Koste & Shiel, 1983
Loc: Billabongs, Magela Ck, N.T.; 13.vi.1979; Lake Grace area, southwest W.A.; xii.1981.
Lit: Koste *et al.* (1983).

Keratella quadrata dispersa (Carlin), 1943
Loc: Yarra R. near Ivanhoe, Vic.; 14.iii.1976.
Lit: Berzins (1982).

Family Euchlanidae Bartos, 1959

E. pyriformis Gosse, 1851
Loc: Moorabool R., Ballan, Vic.; 9.vii.1954.
Lit: Berzins (1982).

Dipleuchlanis elegans (Wierzejski), 1893
Loc: L. Catani, Mt Buffalo, Vic. (= *D. paludosa* Hauer, 1936); 25.ii.1955.
Lit: Berzins (1982).

D. propatula macrodactyla (Hauer), 1965
Loc: Magela Ck, N.T.; 15.iv.1980; Yarra R. east of Warburton, Vic.; 19.iii.1976.
Lit: Koste (1981), Berzins (1982).

Manfredium eudactylotum (Gosse), 1886
Loc: Magela Ck., N.T., 15.iv.1980; Lake Grace-Norseman area, southwest W.A.; viii.1978, x.1981.
Lit: Koste (1981), Koste *et al.* (1983).

Family Mytilinidae Bartos, 1959

Mytilina acanthophora Hauer, 1938
Loc: Solomon Dam, Lake Moondarra, Qld. Undated.
Coll: P. Hawkins, T. Orr.

M. bisulcata (Lucks), 1912
Loc: Yarra R., Dight's Falls, Vic.; 12.iii.1976.
Lit: Berzins (1982).

M. ventralis f. *longidactyla* Wulfert, 1965
Loc: Magela Ck near Jabiluka, N.T.; 15.iv.1980.
Lit: Koste (1981).

Lophocharis curvata Berzins, 1982
Loc: King Parrot Ck, Kinglake, Vic.; 18.x.1953.
Lit: Berzins (1982). Inadequately figured and described. May be a formalin artefact.

L. oxysternum (Gosse), 1851
Loc: Jackson's Creek, Moorabool R., Vic.; 6.iii.1961, 9.vii.1954.
Lit: Berzins (1982).

Family Trichotriidae Bartos, 1959

Trichotria tetractis var. *similis* (Stenroos), 1898
Loc: Magela Ck near Jabiluka, N.T.; 15.iv.1980.
Lit: Koste (1981).

Macrochaetus altamirai (Arevalo), 1918
Loc: Riddel's Ck, Sunbury, Vic.; 06.iii.1961.
Lit: Berzins (1982) (syn: *M. australiensis* Berzins).

M. danneeli Koste & Shiel, 1983
Loc: Buffalo Billabong, Magela Ck, N.T.; 10.xi.1980.
pH 5.38, 30.9°C, O_2 4.15 ppm, 29 μS cm⁻¹.
Lit: Koste & Shiel (1983).

Family Colurellidae Bartos, 1959

Colurella colurus (Ehrenberg), 1830
Loc: Moorabool R., Yarra R., Mt Donna Buang, Vic.; 9.vii.1954, 25.ix.1962, 12.iii.1976.
Lit: Berzins (1982).

C. tesselata (Glascott), 1983
Loc: Coghill's Ck, Vic.; 11.vi.1953.
Lit: Berzins (1982).

C. bicuspidata uncinata (Ehrenberg), 1832
Loc: widespread, Victoria, perennial.
Lit: Berzins (1982).

Lepadella acuminata sexcostata (Bartos), 1955
Loc: Coghill's Ck; L. Catani, Mt Buffalo, Vic.; 11.vi.1953, 25.ii.1955.
Lit: Berzins (1982).

L. acuminata septemcostata Berzins, 1982
Loc: L. Catani, Mt Buffalo, Vic.; 25.ii.1955.
Lit: Berzins (1982).

L. amphitropis Harring, 1916
Loc: Barker's Ck, Castlemaine; Yarra R., Vic.;
   21.iv.1953, 19.iii.1976.
Lit: Berzins (1982).

L. amphitropis victoriensis Berzins, 1982
Loc: Middle Tarwin R., Vic.; 01.v.1953.
Lit: Berzins (1982).

L. apsida Harring, 1916
Loc: L. Euramoo, Qld; viii.1978. Magela Ck, N.T.;
   15.iv.1980.
Lit: Green (1981), Koste (1981).

L. buangensis Berzins, 1982
Loc: Mt Donna Buang, Vic.; 25.ix.1962.
Lit: Berzins (1982). The species is poorly figured.
   The resemblance to *L. patella* (Muller) was noted
   by Berzins (1982 p. 11, Fig. 5) and we consider
   L. buangensis a synonym.

L. chorea Berzins, 1982
Loc: Hunter R. near Gundy, N.S.W. (?11.xi.1953).
Lit: Berzins (1982). Also very poorly figured, and
   possibly a formalin artefact.

L. decora Berzins, 1982
Loc: Loddon R., Vic.; 10.vi.1953.
Lit: Berzins (1982).

L. latusinus f. *mucronata* Koste, 1981
Loc: Magela Ck near Jabiluka, N.T.; 15.iv.1980.
Lit: Koste (1981).

L. lindaui Koste, 1981
Loc: Winmurra Billabong, Magela Ck, N.T.;
   15.iv.1980.
   pH 5.44, 28.5 °C, 6.2 mg λ^{-1} O_2, 23 μS cm^{-1}.
Lit: Koste (1981).

L. minorui Koste, 1981
Loc: Leichhardt Billabong, Magela Ck, N.T.;
   15.iv.1980.
   pH 5.55, 30.1 °C, 5.53 mg λ^{-1} O_2, 58 μS cm^{-1}.
Lit: Koste (1981).

L. oblonga (Ehrenberg), 1834
Loc: Sheepwash billabong, Yea, Vic.; 17.iv.1976.
Coll: R. J. Shiel.

L. ovalis n.f. Koste, 1981
Loc: Nankeen Billabong, Magela Ck, N.T.;
   15.iv.1980.
   pH 5.47, 29.9 °C, 5.45 mg λ^{-1} O_2, 44 μS cm^{-1}.
Lit: Koste (1981).

Lepadella patella patella (Müller), 1786 n. var.
FIG. 1a, b
Loc: Buffalo billabong, Magela Ck, N.T.; 8.xii.1980.
Coll: R. D. Tait.
SAM V3941

In this sample were four *Lepadella* with a circular
lorica which resembled *L. patella* (Müller) described
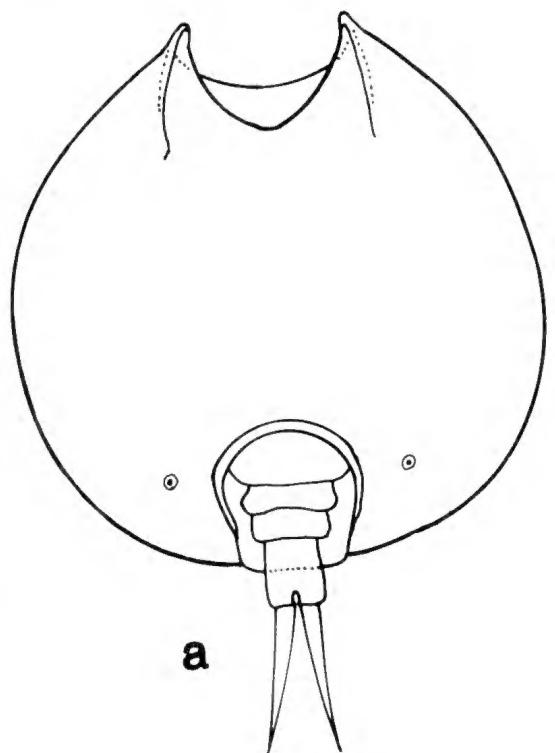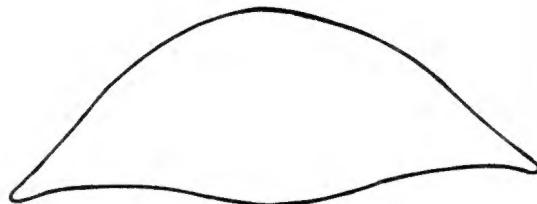
Fig. 1. *Lepadella patella* (O. F. Müller) var. nov. a,
ventral, b, transverse section.

by Wulfert (1960) from a sphagnum pool in middle
Germany (see also Koste (1978b): Pl. 59, Fig. 2K).
Whereas the latter form has a circular foot-opening,
the N.T. form has a semicircular opening with a
quadrangular termination at the end of the ventral
plate. The tropical form is markedly larger: Wulfert
(1960) states that *L. patella* has a lorica length of
70 μm, lorica width 62 μm and toes 21 μm, whereas
the Buffalo Billabong form is 98 μm long, 92 μm
wide, with toes of 24 μm. Both taxa live in acid
biotopes. In the absence of additional information
we document and figure the variant form as an
ecotype, and await more intensive treatment at a
later date.

L. patella biloba (Hauer), 1958
Loc: Yarnup Swamp, near L. Unicup, southwest
W.A.; 8.x.1981.
17.0°C, 1600 µS cm⁻¹.
Lit: Koste *et al.* (1983).

L. quadricarinata (Stenroos), 1898
Loc: Coghill's Ck, Vic.; 11.vi.1953.
Lit: Berzins (1982).

L. quadricarinata sexcarinata Klement, 1959
Loc: Coghill's Ck, Vic.; 11.vi.1953.
Lit: Berzins (1982).

L. rottenburgi (Lucks), 1912
Loc: Riddel's Ck near Sunbury, Vic.; A.; 6.iii.1961.
Lit: Berzins (1982).

L. triba Myers, 1934
Loc: Strathpine pool, Brisbane, Qld; 21.iv.1950.
Lit: Berzins (1982).

Heterolepadella heterodactyla Fadeew, 1925
Loc: Magela Ck near Jabiluka, N.T.; 15.iv.1980.
Lit: Koste (1981).

Family Lecanidae Bartos, 1959

L. (Hemimonostyla) inopinata f. *sympoda* (Hauer),
1929
Loc: Cairns, N.Qld.
Coll: R. Hamond (Det. *L. sympoda* by C. H.
Fernando).

L. bifurca entome Berzins, 1982
Loc: Creswick Ck, Clunes, Vic.; 11.iv.1953.
Lit: Berzins (1982).

L. bulla goniata (Harring & Myers), 1926
Loc: Jackson's Ck, Sunbury, 06.iii.61; Moorabool
R., Ballan, Vic.; 9.vii.1954.
Lit: Berzins (1982).

L. copeis (Harring & Myers),
Loc: Yarra R., near Yarraglen, Vic.; 18.iii.1976.
Lit: Berzins (1982).

L. decipiens (Murray), 1913
Loc: Cairns, Qld.
Coll: P. A. Tyler (Det. C. H. Fernando).

L. elachis Harring & Myers, 1926
Loc: Mine Valley Billabong near Jabiluka, N.T.;
13.vi.1979.
Coll: R. J. Shiel.

L. lamellata thalera (Harring & Myers), 1926
Loc: Forestdale Lagoon near Perth, W.A.
Coll: J. van Alphen.

L. lunaris australis Berzins, 1982
Loc: L. Catani, Mt Buffalo, Vic.; 25.ii.1955.
Lit: Berzins (1982). Doubtful, poorly figured.
?Formalin artefact.

L. lunaris constricta (Murray), 1913
Loc: R. Murray, Blanchetown, S.A. 7.v.1982.
Coll: R. J. Shiel.

L. lunaris perplexa Ahlstrom, 1938
Loc: Yarra R., Yarra Glen, Warburton, Vic. 14, 18,
19.iii.1976.
Lit: Berzins (1982).

L. monostyla (Daday), 1897
Loc: L. Euramoo, Qld; viii.1978.
Lit: Green (1981).

L. obtusa (Murray), 1913
Loc: L. Euramoo, Qld, viii.1978; Coghill's Ck, Vic.;
11.vi.1953.
Lit: Green (1981), Berzins (1982).

L. opias (Harring & Myers), 1926
Loc: Yarra R., McMahon's Ck, Vic.; 19.iii.1976.
Lit: Berzins (1982).

L. perpusilla (Hauer), 1929
Loc: Yarra R., near Ivanhoe, Vic.; 14.iii.1976.
Lit: Berzins (1982).

L. pyriformis (Daday), 1905
Loc: Magela Ck near Jabiluka, N.T., 15.iv.1980; L.
Euramoo, Bromfield Swamp, Atherton
Tableland, Qld, viii.1978; southern Vic.,
11.iv.1955, 11.vi.1953, 6.iii.1961.
Lit: Koste (1981), Green (1981), Berzins (1982).

L. scutata (Harring & Myers), 1926
Loc: Magela Ck floodplain, N.T., 15.iv.1980.
Lit: Koste (1981).

L. tethis (Harring & Myers), 1926
Loc: L. Euramoo, Atherton Tableland, Qld;
viii.1978.
Lit: Green (1981).

L. (M.) unguitata Fadeew, 1925 var. nov.
FIG. 2a, b
Loc: Billabong of Coleman R., Cape Yorke, Qld.
26.vi.1983.
Coll: B. V. Timms.
SAM V3944

A single individual of this species was identified
only from a figure given by Hauer (1938, Fig. 71a, b)
(see also Koste 1978, Fig. 80, 6a-c). The species is
rare, but seems to be cosmopolitan. Wulfert (1966)
described variable ecotypes from the Sokoto R., W.
Africa, and from Indian waters. The characteristic
anterior projections of the lorica were not visible
or were absent on the Cape Yorke variant.
Measurements: Ventral lorica length 104 µm, ventral
lorica width 83 µm, dorsal lorica length 94 µm,
dorsal lorica width 72 µm, toes incl. claws 40 µm,
claws 12 µm.
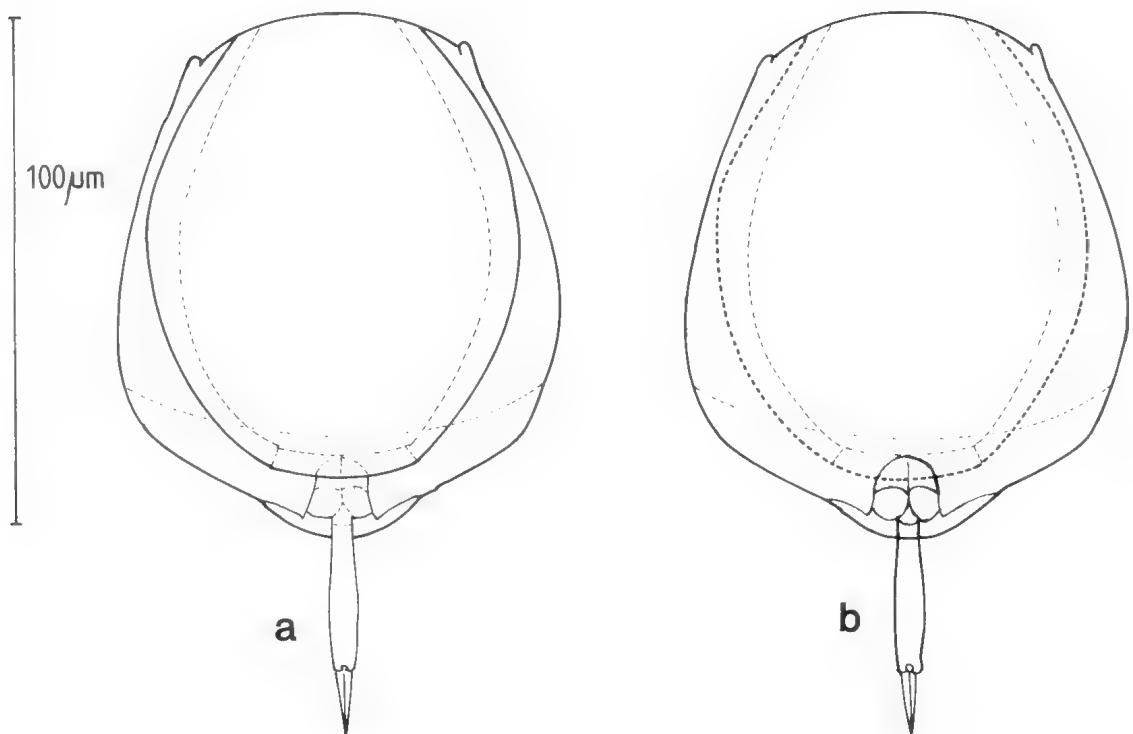
Fig. 2. *Lecane (Monostyla) unguitata* Fadeew, var. nov. a, ventral, b, dorsal.

Lecane (s. str.) aculeata var. *arcula* (Harring), 1914
Loc: Eildon Res., Bonnie Doon, Vic.; 10.xii.1962.
Lit: Berzins (1982). (=*L. arcula* (Harring)).

Lecane aspasia Myers,
Loc: L. Catani, Mt Buffalo, Vic.; 25.ii.1955.
Lit: Berzins (1982).

L. boorali Koste & Shiel, 1983
Loc: Meekatharra, W.A.; 20.viii.1978.
Lit: Koste *et al.* (1983).

L. clara (Bryce), 1892
Loc: Moorabool R., Ballan, Vic.; 9.vii.1954.
Lit: Berzins (1982).

L. curvicornis nitida (Murray), 1913
Loc: Magela Creek floodplain near Jabiluka, N.T.;
 15.iv.1980.
Lit: Koste (1981).

L. formosa Harring & Myers, 1926
Loc: Hunter R. near Gundy, N.S.W.; 11.xi.1953.
Lit: Berzins (1982).

L. hastata (Murray), 1913
Loc: Lake Grace-Meekatharra area, southwest
 W.A.; xi.1981.
Lit: Koste *et al.* (1983).

L. inermis (Bryce), 1892
Loc: Creswick Ck, Moorabool R., Serpentine Ck,
 Vic.; 11.iv.1953, 9.vii.1954, 22.iv.1953.
Lit: Berzins (1982).

L. levistyla (Olofsson), 1917
Loc: Magela Ck floodplain near Jabiluka, N.T.;
 15.iv.1980.
Lit: Koste (1981).

L. mira (Murray), 1913
Loc: Strathpine pool, Brisbane; 21.iv.1950.
Lit: Berzins (1982).

L. mylacris Harring & Myers, 1926
Loc: Creswick Ck, Clunes, Vic.; 11.iv.1953.
Lit: Berzins (1982).

L. ploenensis (Voigt), 1902
Loc: Dunwich, Qld; 03.x.1959.
Lit: Russell (1961).(=*L. signifera* var. *ploenensis*
 (Voigt) after Wiszniewski (1954)).

L. pusilla Harring, 1914
Loc: Bromfield Swamp, Qld; viii.1978., Sunbury,
 Vic.; 6.iii.1961.
Lit: Green (1981), Berzins (1982).

L. pyrrha Harring & Myers, 1926
Loc: Dam, Beaufort, Vic.; 04.xi.1953.
Lit: Berzins (1982).

L. rhytida Harring & Myers, 1926
Loc: Yarra R., McMahon's Ck, Vic.; 19.iii.1976.
Lit: Berzins (1982).

L. stichea f. *intrasinuata* (Olofsson), 1917
Loc: Winmurra billabong, Magela Ck, N.T.;
15.04.1980.
Coll: R. D. Tait.

L. subtilis Harring & Myers, 1926
Loc: Winmurra billabong, Magela Ck, N.T.;
15.iv.1980.
Coll: R. D. Tait.

Lecane tasmaniensis sp. nov.
FIG. 3 a,b

Material: 11 contracted females, sample No. 1120,
in formalin.

Holotype: loricate female, sample No. 1120. Coll:
22.iv.1984. R. J. Shiel. SAM V3942.

Paratypes: SAM V3943.

Type locality: Roadside pool, button grass plain
near turnoff to McAuliffe's Weir on Lake St Clair
road, Tasmania (42°11'S/142°56'E).

Description: Lorica outline (Fig. 3a) elongate, oval;
anterior dorsal margin straight; triangular cusps or
projections at the external angles extend past ventral
margin; dorsal plate unmarked, wider than ventral
plate; ventral plate with distinct transverse ridge
across first toe segment from which parallel lines
run towards the anterior margin (Fig. 3a); posterior
segment rounded caudally; coxal plates medium,
rounded; first foot joint rectangular, distinct;
second foot joint square; toes less than half body
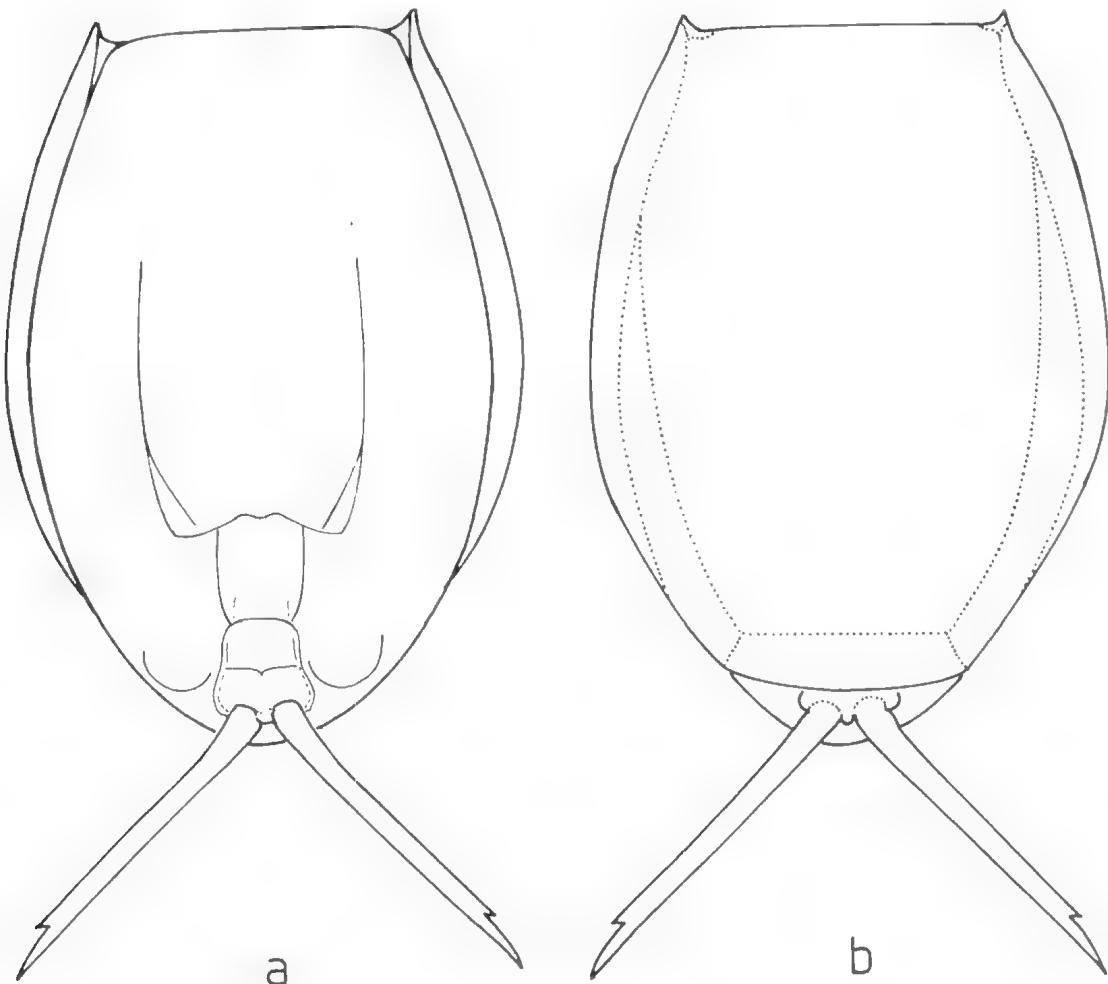
Fig. 3. *Lecane tasmaniensis* sp. nov. a, ventral, b, dorsal.

length, parallel-sided ending in short claws with basal spicules.

Measurements (μm): Total length 155-168; dorsal plate length -115, width -86; ventral plate length -126, width -79; anterior points -58; length of toes incl. claw -61; claw 10-12.

Discussion: In habit, the new species resembles *L. acronycha* Harring & Myers, 1926 and *L. curvicornis* (Murray), 1913; however the measurements of these taxa, in the same sequence as given above are: *L. acronycha* -290; 111-162, -136; 125-182, 95-113; -80; -102; -12 and *L. curvicornis* -280; 110-120, 95-112; 130-145, 105-116; -63; -79; 8-13.

L. tasmaniensis is markedly smaller in most respects, and is further characterized by the distinctly visible first toe segment under a transvers ridge, with nearly quadrangular lines above it (Fig.3 a).

L. tudicola Harring & Myers, 1926
Loc: Dam, Beaufort, Vic.; 4.xi.1953.
Lit: Berzins (1982).

L. venusta Harring & Myers, 1926
Loc: Coghill's Ck., Vic.; 11.vi.1953.
Lit: Berzins (1982).

Family Proalidae Bartos, 1959

Bryceella voigti Rodewald, 1934
Loc: Bombala, N.S.W., moss and tree stump mould; 8.i.1950.
Lit: Berzins (1982).

Proales doliaris (Rousselet), 1895
Loc: Riddel's Ck, near Sunbury, Vic.; 6.iii.1961.
Lit: Berzins (1982).

Family Lindiidae Remane, 1933

Lindia annecta Harring & Myers, 1922
Loc: Mt Buffalo, Vic.; 10.xii.1962.
Lit: Berzins (1982).

L. truncata (Jennings), 1894
Loc: Yarnup Swamp, near L. Unicup, southwest W.A.; 8.x.1981.
Lit: Koste *et al.* (1983).

Family Notommatidae Remane, 1933

Monommata maculata Harring & Myers, 1924
Loc: Magela Ck, N.T., 14.iv.1980; L. Grace-Norseman area, southwest W.A.; ix.1981; dam near Chillagoe, N. Qld, 12.vii.1983.
Lit: Koste (1981), Koste *et al.* (1983), Qld material coll. B. V. Timms.

Dorystoma caudata (Bilfinger), 1894
Loc: Yarnup Swamp, southwest W.A.; 8.x.1981.
Lit: Koste *et al.* (1983).

Itura viridis (Stenroos), 1898
Loc: Reservoir, Trentham, Vic.; 5.xii.1984.
Coll: I. J. Powling.

Eosphora anthadis Harring & Myers, 1922
Loc: near L. Logue, Eneabba Rd, southwest W.A.; 30.ix.1981.
Lit: Koste *et al.* (1983).

E. thoa Harring & Myers, 1924
Loc: Forestdale Lagoon, southwest W.A.
Coll: J. van Alphen.

E. cf. thoides Wulfert, 1935
Loc: Buffalo Billabong, Magela Creek near Jabiluka, N.T.; 8.xii.1980.
Lit: Koste & Shiel (1983).

Resticula gelida Harring & Myers, 1922
Loc: Yarnup Swamp, southwest W.A.; 8.x.1981.
Lit: Koste *et al.* (1983).

Notommata cf. *triangulata* (Kirkman), 1906
Loc: Magela Creek floodplain near Jabiluka, N.T.; 15.iv.1980.
Lit: Koste (1981).

Cephalodella apocolea Myers, 1924
Loc: Magela Ck floodplain near Jabiluka, N.T.; 15.iv.1980.
Lit: Koste (1981).

C. auriculata (Muller), 1773
Loc: Creswick Ck, Tarwin R., Vic.; iv, v.1953.
Lit: Berzins (1982).

C. euderbyi Wulfert, 1940
Loc: Serpentine Ck, Bears Lagoon, Vic.; 22.iv.1953.
Lit: Berzins (1982).

C. exigua (Gosse), 1886
Loc: Clunes, Gippsland, Mt Buffalo, Vic.; iv, v.1953, xii.1962.
Lit: Berzins (1982).

C. gracilis (Ehrenberg), 1832
Loc: widespread, Vic.; prob. perennial.
Lit: Berzins (1982).

C. hoodi (Gosse), 1896
Loc: Tarwin R., Vic.; 1, 7.v.1953.
Lit: Berzins (1982). Berzins also recorded *C. remanei* Wiszniewski from Castlemaine, Vic. (= *C. hoodi*. For synonymy see Koste 1978b p. 351).

C. intuta Myers, 1924
Loc: Magela Ck floodplain near Jabiluka, N.T.; 15.iv.1980.
Lit: Koste (1981).

C. misgurnus Wulfert, 1937
Loc: Magela Ck floodplain near Jabiluka, N.T.; 15.iv.1980.
Lit: Koste (1981).

C. megalocephala (Glascott), 1893
Loc: Wentworth Falls, N.S.W.; 22.xi.1953.
Lit: Berzins (1982).

C. myersi Wiszniewski, 1934
Loc: Scrubby Ck, Whittlesea, Vic.; 30.v.1955.
Lit: Berzins (1982).

C. nana Myers, 1924
Loc: Creswick Ck, Clunes, Vic.; 11.iv.1953.
Lit: Berzins (1982).

C. parasitica (Jennings), 1894
Loc: Diggers Ck, Mt Kosciusko, N.S.W.; 11.iv.1961.
Lit: Berzins (1982).

C. sterea (Gosse), 1887
Loc: Magela Ck floodplain near Jabiluka, N.T.;
   15.iv.1980.
Lit: Koste (1981).

C. tuntilloides Hauer, 1935
Loc: Bromfield Swamp, Qld; viii.1978.
Lit: Green (1981).

Family Trichocercidae Remane, 1933

Trichocerca bidens (Lucks), 1912
Loc: Creswick Ck, Clunes, 11.iv.1953; L. Catani, Mt
   Buffalo, 10.xii.1962; Yarra R. Warburton, Vic.;
   19.iii.1976.
Lit: Berzins (1982).

T. cudonta (Hauer), 1938
Loc: Moorabool R., Ballan, Vic.; 9.vii.1954.
Lit: Berzins (1982). (=*T. myersi* Hauer, 1939).

T. fusiformis Levander, 1894
Loc: Magela Ck floodplain near Jabiluka, N.T.;
   15.iv.1980.
Lit: Koste (1981).

T. gracilis (Tessin), 1890
Loc: Solomon Dam, Qld. Undated.
Coll: P. Hawkins.

T. iernis (Gosse), 1887
Loc: Yarra R., Warburton, Vic.; 14, 19.iii.1976.
Lit: Berzins (1982).

T. inermis (Linder), 1904
Loc: Sheepwash Billabong, Yea, Vic.; 8.v.1982.
Coll: R. J. Shiel.

T. insulana Hauer, 1937
Loc: Magela Ck floodplain near Jabiluka, N.T.;
   15.iv.1980.
Lit: Koste (1981).

T. intermedia (Stenroos), 1898
Loc: Bromfield Swamp, Qld; viii.1978.
Lit: Green (1981).

T. macera (Gosse), 1886
Loc: L. Catani, Mt Buffalo, Vic.; 25.ii.1955;
   Gamboola Stn Dam, Cape Yorke, 12.vii.1983.
Lit: Berzins (1982), Qld material coll. B. V. Timms.

T. montana Hauer, 1956
Loc: Winmurra Billabong, Magela Creek, N.T.;
   15.iv.1980.
Coll: R. D. Tait.

T. musculus (Hauer), 1936
Loc: Diggers Ck, Mt Kosciusko, N.S.W., 11.iv.1961;
   Lake Grace-Meekatharra area, southwest W.A.;
   ix, x.1981.
Lit: Berzins (1982), Koste *et al.* (1983).

T. rattus cristata Harring, 1913
Loc: Sunbury, Whittlesea, Vic.; 6.v.1955, 30.iii.1961.
Lit: Berzins (1982).

T. rattneri (Donner), 1953
Loc: Dam near Chillagoe, Qld; 12.vii.1983.
Coll: B. V. Timms.

T. sulcata (Jennings), 1894
Loc: Avoca R., Gowar East, Vic.; 23.iv.1953.
Lit: Berzins (1982).

T. uncinata (Voigt), 1902
Loc: Tabrabucca Ck, Barrington, N.S.W.; 12.xi.1953.
Lit: Berzins (1982).

T. vernalis (Hauer), 1936
Loc: Serpentine Ck, Bears Lagoon, Vic.; 22.iv.1953.
Lit: Berzins (1982).

Family Gastropodidae Remane, 1933

Ascomorpha saltans indica Wulfert, 1966
Loc: L. Barracoota, Vic., 20.i.1975.
Lit: Berzins (1982).

Family Synchaetidae Remane, 1933

Synchaeta lackowitziana Lucks, 1912
Loc: Moorabool R., Vic.; 9.vii.1954; R. Murray,
   Tailem Bend, S.A.; 10.x.1983.
Lit: Berzins (1982), S.A. material coll. R. J. Shiel.

Polyarthra major Burckhardt, 1900
Loc: Coliban Res., Kyneton, 06.iii.1961; L. Catini,
   Mt Buffalo, 25.ii.1955.
Lit: Berzins (1982).

P. minor Voigt, 1904
Loc: Magela Ck floodplain near Jabiluka, N.T.;
   15.iv.1980.
Lit: Koste (1981).

Family Asplanchnidae Harring & Myers, 1926
Asplanchna brightwelli asymmetrica spp. nov.
FIG. 4a, b
Material: 12 females, formalin preserved, sample
#876; 9 females, sample #1005.
Iconotype: trophi, adult female, Fig. 4, sample #876,
coll. 4.i.1981 P. Hawkins.
Paratypes: SAM V3945.
Type locality: Solomon Dam, Palm Island, near
Townsville, Qld (18°44'S, 146°35'E).
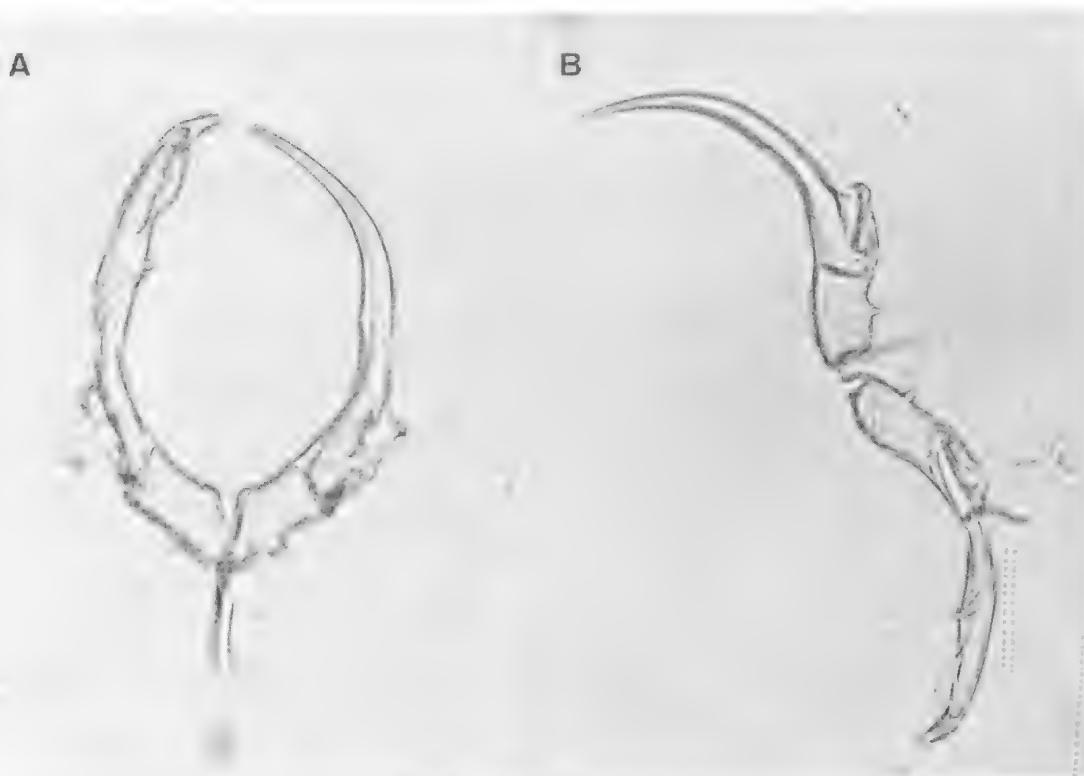
Fig. 4. *Asplanchna brightwelli asymmetrica* ssp. nov. A, trophi apical, length 130 m, B, trophi compressed under coverslip.

Description: Typical saccate illoricate form; horseshoe-shaped vitellaria belonging to the *A. brightwelli-intermedia-sieboldi* group (Koste 1978, Salt *et al.* 1978, Gilbert *et al.* 1979). Trophi (Fig. 4a, b) asymmetrical, rami (r) with short medial inner tooth only on left side, rudimentary swelling on right; right ramus smaller, more tapered and arched than that of typical form (cf. Fig. 5). In addition, the right ramus lacks a second uncus (U_2 and a lamella (la) before the ramipoint (rp).

Measurements: Comparative measurements/ features of f. typ. are given in parentheses after those of the n. ssp.: Trophi length: 130 μm (104-156); apophysis (Fig. 4: ap, sap): equal (equal); fulcrum (f): equal (equal); inner marginal teeth: 1 small on left only (2 small symmetrical); lamella before ramipoints (la): left only (2 symmetrical); rami (r): conspicuously asymmetrical (symmetrical); uncus (U_1): equal (equal); uncus (U_2): left only (2 symmetrical); subterminal rami tooth: equal (left only).

Discussion: It was not possible in the preserved material to count the nuclear number of gastric- and yolk glands, which are used additionally to verify *Asplanchna* taxa, however the features of the
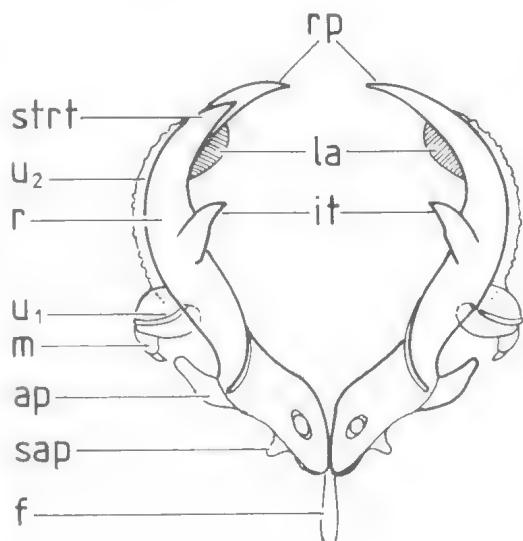
Fig. 5. Trophi of *Asplanchna brightwelli* (Gosse) (ap = apophysis on the bulla of the ramus; f = fulcrum; it = inner teeth protruding from rami inner margin; la = lamella behind ramal points; m = manubrium; r = ramus; rp = ramipoints; sap = subapophysis; strt = second rami tooth; u_1 = first uncus; U_2 = second uncus).

characteristic asymmetrical trophi in our opinion distinctly separate this taxon from *A. brightwelli* (Gosse), which it most resembles.

Asplanchna herricki De Guerne, 1888
Loc: Albert Park, Vic.
Lit: Evans (1951).

Family Dicranophoridae Remane, 1933
Alberta naidis Bousfield, 1886
Loc: Magela Ck floodplain near Jabiluka, N.T.; 15.iv.1980.
Lit: Koste (1981).

Aspelta aper (Harring), 1913
Loc: Yarra R., Vic.; 14.iii.1976.
Lit: Berzins (1982).

A. circinator (Gosse), 1886
Loc: Plenty R. Morang S., Vic.; 30.x.1954.
Lit: Berzins (1982).

A. neboisi Berzins, 1982
Loc: Yarra R. near Ivanhoe, Vic.; 14.iii.1976.
Lit: Berzins (1982).

Balatro calvus Claparède, 1867
Loc: Winmurra Billabong, Magela Ck, N.T.; 15.iv.1980.
Lit: Koste (1981).

Dicranophorus epicharis Harring & Myers, 1928
Loc: Magela Ck floodplain near Jabiluka, N.T.; 15.iv.1980.
Lit: Koste (1981).

D. halbachi Koste, 1981
Loc: Winmurra Billabong, Magela Ck, N.T.; 15.iv.1980.
Lit: Koste (1981).

D. hercules Wisniewski, 1932
Loc: Magela Ck floodplain near Jabiluka, N.T.; 15.iv.1980.
Lit: Koste (1981).

D. robustus Harring & Myers, 1928
Loc: Norseman-Kalgoorlie area, southwest W.A.; x.1981.
Lit: Koste et al. (1983).

Encentrum mnium Berzins, 1982
Loc: Bombala, N.SW. In mould on a eucalyptus stump. 28.xii.1949.
Lit: Berzins (1982). Doubtful species on the basis of poor figures.

E. proxdendrus Berzins, 1982
Loc: Bombala, N.SW. In mould on a eucalyptus stump. 28.xii.1949.
Lit: Berzins (1982). As above, figures are inadequate for a new species' description. Doubtful record.

Wierzejskiella velox (Wiszniewski), 1932
Loc: Yarnup Swamp, W.A.; 8.x.1981.
Lit: Koste et al. (1983).

Family Testudinellidae Bartos, 1959
Pompholyx tubulosa Berzins, 1982
Loc: L. Purumbete, Vic.; 29.vii.1953.
Lit: Berzins (1982). Poorly figured, ?formalin artefact. = *P. complanata* Gosse.

### *Testudinella greeni* Koste, 1981
Loc: Leichhardt Billabong, Magela Ck, N.T.; 15.iv.1980
Lit: Koste (1981).

Testudinella husseyi sp. nov.
FIG. 6:1a, b
Material: 13 formalin preserved females, sample #998.
Holotype: 1 adult female, sample #998, coll. 8.vii.1983 B. V. Timms. SAM V3946.
Paratypes: SAM V3947.
Type locality: Dune lake near Cooktown, Cape Yorke, North Qld (15°28'S, 145°15'E).
Description: Shape of lorica oval; anterior margin with five tooth-shaped relatively long, keeled projections, two on either side of a median shorter tooth. In contrast, *T. patina patina* (Hermann), 1783 (see Fig. 6:2) has only a soft rounded projection. The new sp. has at the anterior ventral lorica margin a median, relatively broad notch between two short keels, which is unknown in related species.
Measurements: Lorica length 140-150 μm; lorica width 112 μm; width of semicircular foot-opening 15-18 μm; median notch in ventral plate 11 μm deep.
Discussion: The morphological group *T. patina-ohlei-mucronata* (after Koste 1978) have variable short tongues at the anterior dorsal margin of the lorica. The new species most resembles *T. ohlei*, but differs in the form of the dorsal and ventral anterior lorica margin. *T. ohlei* Koste has only three more-rounded (tongue-shaped) elongations of the dorsal anterior margin [see Koste 1978a, b, cf. also *T. patina trilobata* Anderson & Shephard and *T. kostei* De Ridder (De Ridder 1983)].
Etymology: The new species is named after Charles G. Hussey, of the British Museum (Natural History), in recognition of his work on the Rotifera of the U.K.

T. munda Berzins, 1982
Loc: Creswick Ck, Clunes, Vic.; 11.iv.1953.
Lit: Berzins (1982). Not distinguishable from *T. amphora* Hauer on the basis of the figures and regarded here as synonymous.

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100 μm

1a

1b

2
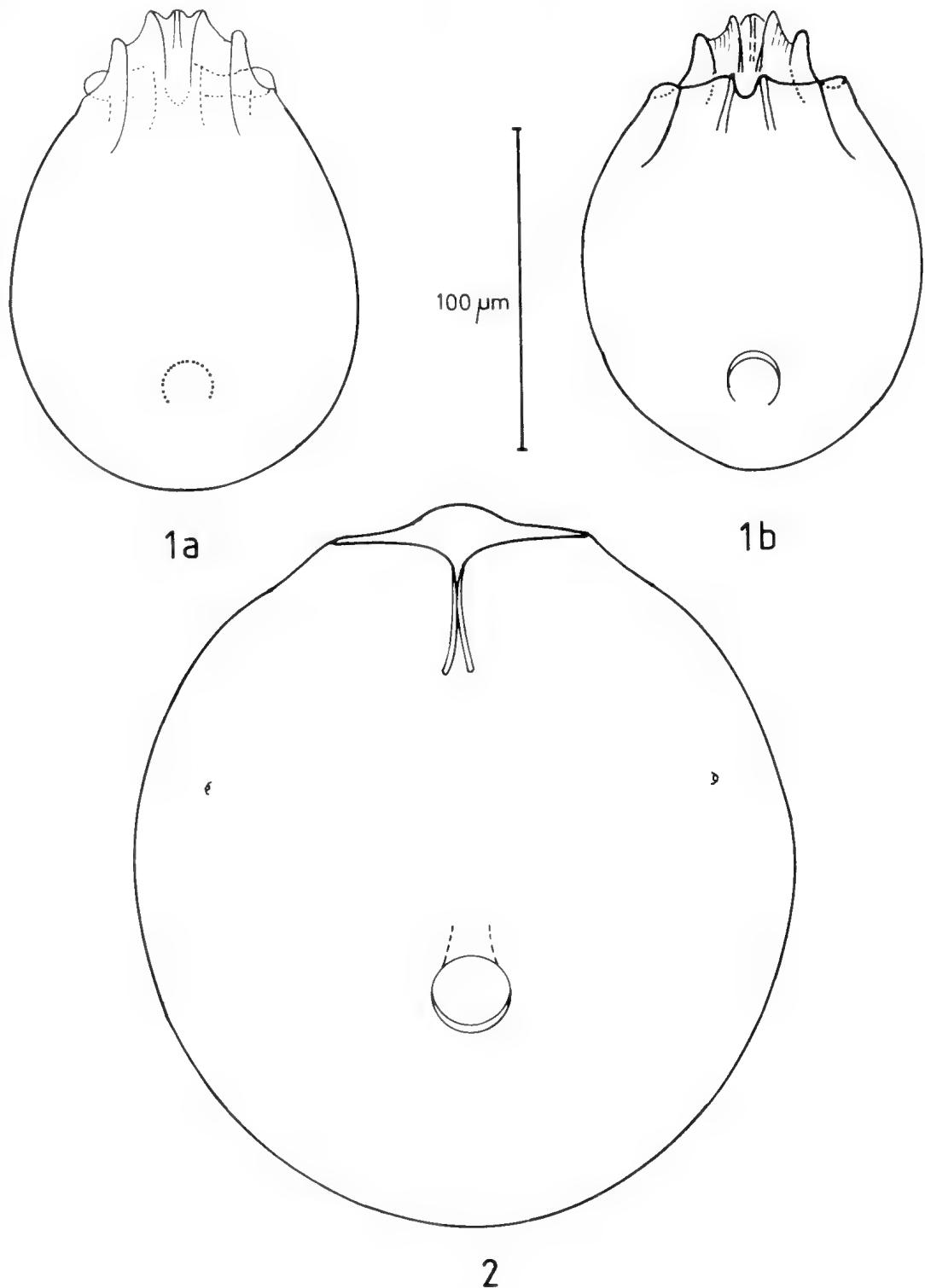
Fig. 6:1 *Testudinella husseyi* sp. nov. a, dorsal, b, ventral.

6:2 *Testudinella patina* (Hermann) from Tasmania, length of lorica 245 μm, width 216 μm, ventral view.
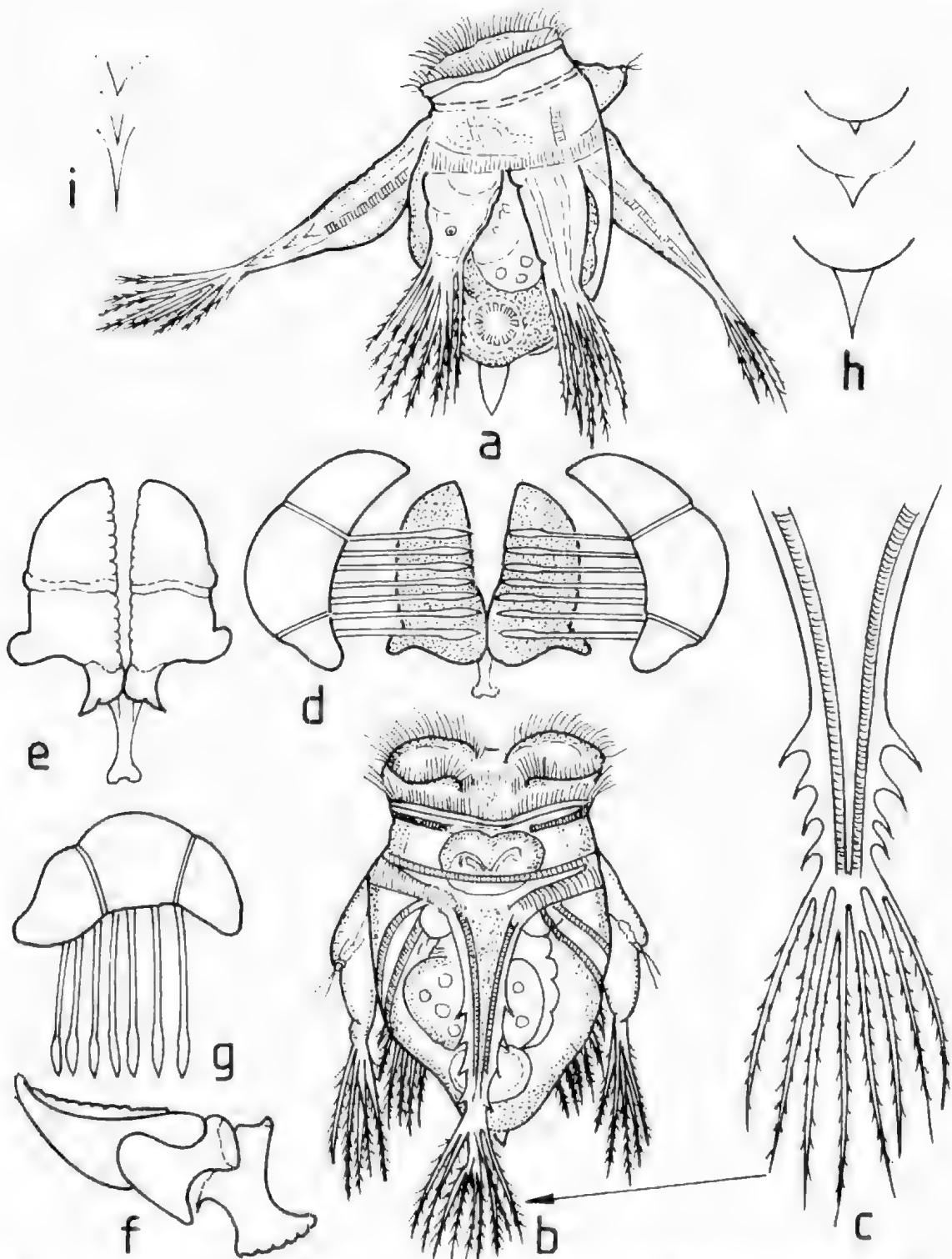
Fig. 7 *Hexarthra oxyuris* (Sernov) a, lateral, b, ventral, c, ventral armlike appendage, d, trophi apical, e, rami and fulcrum, f, rami and fulcrum lateral, g, manubrium and uncus teeth, h, caudal projections of *H. oxyuris* from Tasmania, i, caudal projections of *H. barracootica* Berzins, 1982 a-d from Tasmanian population, e-f from W.A. population.

T. neboissi Berzins, 1982

Loc: Creswick Ck, Clunes, Vic.; 11.iv.1953.

Lit: Berzins (1982). Inadequately figured. Resembles *T. emarginula* (Stenroos) and must be considered a doubtful record.

T. patina intermedia (Anderson), 1889

Loc: L. Barracoota, Vic.; 20.i.1975.

Lit: Berzins (1982).

T. semiparva Hauer, 1938

Loc: Magela Ck floodplain near Jabiluka, N.T.; 15.iv.1980.

Lit: Koste (1981).

T. vidzemensis Berzins, 1943

Loc: Creswick Ck, Clunes, Vic.; 11.iv.1953.

Lit: Berzins (1982).

Family Flosculariidae Harring, 1913

Octotrocha speciosa Thorpe, 1893

Loc: Buffalo Billabong, Magela Ck, N.T.; 8.xii.1980.

Lit: Tait *et al.* (1984).

Sinantherina ariprepes Edmondson, 1939

Loc: Island billabong, Magela Ck., N.T.; 15.iv.1980.

Coll: R. D. Tait.

Family Hexarthridae Bartos, 1959

Populations of a species of *Hexarthra* found in W.A. (#788) and Tasmania (#1146) were determined to be:

H. oxyuris Sernov, 1903
FIG. 7a-i.

Syn: *Hexarthra fennica* var. *oxyuris* (Sernov), 1903

Loc: L. Barracoota, Vic.; 20.i.1975; Norseman-Albany area, southwest W.A., x.1981; Farm dam 8 km east of St Helens, Tas.; 24.iv.1984; peaty, acid water, 14°C

Lit: Berzins (1982), W.A. material coll. M. A. Brock, Tas. material coll. R. J. Shiel.

Regarded as a variety of *H. fennica* (Levander), 1892 by Hauer (1941), this rotifer is characterized by intra-population variability in caudal spine

development and unci teeth number. The only difference between *H. fennica* and *H. oxyuris* is in the caudal armature. The caudal spine may be absent, as in *H. fennica,* or varying between individuals (both Tas. and W.A. populations) as in Fig. 7h (cf. Fig. 7i for a population described as *H. barracootica* Berzins, 1982). Most of our specimens had 7/7 unci teeth (cf. Fig. 6d, g), however some had 6/7, 7/8. Koste (1977) describes the variability: 7/7, 8/7. 7/8, 6/6, 6/7. Therefore, *H. barracootica,* which was described by Berzins (1982) as "very like *H. oxyuris* . . . but trophi with only 6/6 teeth" apparently is a synonym of *H. oxyuris.* Further, the ventral armlike appendages of both taxa have the same number of bristles (8) (Fig. 7c, cf. Berzins 1982 Fig. 60a)

Family Collothecidae Bartos, 1959

Collotheca tenuilobata (Anderson), 1889

Loc: L. Catani, Mt Buffalo, Vic.; 25.ii.1955.

Lit: Berzins (1982).

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SOME EFFECTS OF SEASON AND GEOGRAPHICAL ASPECT ON ANTS (HYMENOPTERA: FORMICIDAE) IN THE MT LOFTY RANGES, SOUTH AUSTRALIA

BY P. J. M. GREENSLADE

Summary

Ants were sampled for a year in Eucalyptus baxteri-E. obliqua forest at Bridgewater near Adelaide with two transects of pitfall traps, one on a well isolated northwest-facing slope, the other on a more shaded southwest-facing one. The fauna was typical of humid parts of South Australia in that the total of 32 species included both cryptic ants (active mainly within soil and litter) and epigaeic species (active on and above the soil surface) nesting either in soil or arboreally. Catches of epigaeic species had a pronounced maximum in late spring and early summer. Catches of cryptic species did not show such marked seasonal variation. The two transects differed substantially. On the northwest slope catches reached a maximum in February; species with distributions extending to areas drier than Bridgewater predominated, Eyrean elements were present in the fauna, and Iridomyrmex species and associated taxa were frequent. On the southwest slope catches declined in late summer and species extending into areas wetter than Bridgewater, with highest catches earlier (in November), were predominant, Eyrean elements were less, and Bassian elements were more frequent than on the northwest slope; a higher incidence of cryptic and other ground-living ants compensated for a reduction in frequency of Iridomyrmex and associates. Community structure on the southwest slope, but not on the northwest, resembled that of an ant community that has been studied in Eucalyptus obliqua woodland in southern Victoria. As a whole this Bridgewater ant fauna is a transitional one on the elevation gradient of rainfall in the Mt Lofty Ranges. The presence or absence of Myrmecia forficata on one hand, and of M. pyriformis and Iridomyrmex purpureus on the other may serve as indicators of this transition. On this site associations of invertebrates (ant communities) differ in composition according to aspect within a single floristic and structural vegetation unit. This introduces a brief discussion of the conservation of invertebrates and their use in environmental assessment.

SOME EFFECTS OF SEASON AND GEOGRAPHICAL ASPECT ON ANTS (HYMENOPTERA: FORMICIDAE) IN THE MT LOFTY RANGES, SOUTH AUSTRALIA

by P. J. M. GREENSLADE [*]

Summary

GREENSLADE, P. J. M. (1985) Some effects of season and geographical aspect on ants (Hymenoptera: Formicidae) in the Mt Lofty Ranges, South Australia. *Trans. R. Soc. S. Aust.* **109**(1), 17-23, 28 June, 1985.

Ants were sampled for a year in *Eucalyptus baxteri-E. obliqua* forest at Bridgewater near Adelaide with two transects of pitfall traps, one on a well insolated northwest-facing slope, the other on a more shaded southwest-facing one. The fauna was typical of humid parts of South Australia in that the total of 32 species included both cryptic ants (active mainly within soil and litter) and epigaeic species (active on and above the soil surface) nesting either in soil or arboreally. Catches of epigaeic species had a pronounced maximum in late spring and summer. Catches of cryptic species did not show such marked seasonal variation. The two transects differed substantially. On the northwest slope catches reached a maximum in February; species with distributions extending to areas drier than Bridgewater predominated, Eyrean elements were present in the fauna, and *Iridomyrmex* species and associated taxa were frequent. On the southwest slope catches declined in late summer and species extending into areas wetter than Bridgewater, with highest catches earlier (in November), were predominant. Eyrean elements were less, and Bassian elements were more frequent than on the northwest slope; a higher incidence of cryptic and other ground-living ants compensated for a reduction in frequency of *Iridomyrmex* and associates. Community structure on the southwest slope, but not on the northwest, resembled that of an ant community that has been studied in *Eucalyptus obliqua* woodland in southern Victoria. As a whole this Bridgewater ant fauna is a transitional one on the elevational gradient of rainfall in the Mt Lofty Ranges. The presence or absence of *Myrmecia forficata* on one hand, and of *M. pyriformis* and *Iridomyrmex purpureus* on the other may serve as indicators of this transition. On this site associations of invertebrates (ant communities) differ in composition according to aspect within a single floristic and structural vegetation unit. This introduces a brief discussion of the conservation of invertebrates and their use in environmental assessment.

Introduction

The ant communities of South Australia's forests and woodlands have been described recently in general terms (Greenslade, in press). Some of the ants of one open forest locality in the Mt Lofty Ranges are discussed here in greater detail. Although Gentilli (1972) stressed the complexity of the climatic influences that affect southern South Australia, the climate of the Mt Lofty Ranges near Adelaide is unequivocally mediterranean. Summers are hot and dry, winters cool and wet, imposing a double stress on biota. Climate can be both moderated and accentuated by aspect. The distributions of the *Eucalyptus* species that make up the forests and woodlands of the Mt Lofty Ranges are determined primarily by soil type and the gradient of increasing precipitation that accompanies increasing elevation, but Specht & Perry (1948) showed that aspect is involved as well. Compared with south-facing slopes, north-facing ones are likely to be warmer in winter but excessively hot and dry in the summer. Aspect also affects invertebrates in this area. It influences the distribution of mounds of the termite *Nasutitermes*

exitiosus (Hill) (Wood & Lee 1971) and the structure of ant populations and communities (Greenslade 1975, in press; P. J. M. Greenslade & C. J. Johnston, unpubl.). Effects may be complex. The interaction of aspect, vegetation and insolation determines the soil climate which, in turn, affects leading members of ant communities with secondary effects on subordinate species.

In 1983-84, Dr G. H. Baker used pitfall traps at Bridgewater near Adelaide for a year to sample a population of the introduced millipede *Ommatoiulus moreletii* (Lucas) and to monitor its potential ground-living predators. This paper reports on the ants taken in these traps. They were divided between a well insolated northwest-facing slope and a more shaded southwest-facing one so their catches present another opportunity to investigate the interaction between the effects of season and aspect.

Previous work involving invertebrates on this site has dealt with the biology of *O. moreletii* (Baker 1978a-c) and the inputs of dead plant material to the forest floor and its disposal by termites (Lee & Butler 1977; Lee & Correll 1978; Lee & Wood 1968) and other soil biota (Hutson & Veitch 1983). Data and material provided by Baker and Hutson have been used to show how different methods of sampling soil fauna can yield differing results

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(Greenslade & Greenslade 1983). For example, the number of ant species captured in pitfall traps reaches a maximum in summer when temperatures are high and ants are most active on the soil surface. On the other hand numbers extracted from soil and litter samples, for the most part different species, are greatest in spring and autumn, indicating direct or indirect limitation by low temperatures in winter and by low soil moisture and high temperatures and saturation deficits in summer.

Site and Methods

The Engelbrook Reserve at Bridgewater consists of an open forest of *Eucalyptus baxteri* and *E. obliqua* with a sclerophyll shrub layer, growing on an acid yellow duplex soil. Mean annual rainfall is c.1000 mm (cf. summit of Mt Lofty, 1690 mm). Ants and other surface fauna were sampled with pitfall traps, consisting of plastic jars, 9 cm diameter by 9 cm deep. They were used without killing agent and preservative and a lid was supported above them to prevent the entry of rainwater. Two transects each of 20 traps 10 m apart were laid out, c. 350 m above sea level, one on a northwest-facing slope, the other adjacent to the first, on a slope that faced southwest. The vegetation on the two slopes was very similar apart from a slightly higher density of eucalypts on the more shaded southwest slope (G. H. Baker, pers. comm.). The site is described in more detail by Hutson & Veitch (1983).

Traps were cleared at weekly intervals from March 1983-March 1984 and each week ants were pooled from all traps. These traps were not primarily intended for ants and are not very effective for them, due to predation within and escape from the traps. Consequently the data used here are monthly mean numbers of species per transect or total records of species in traps.

Results

The total of 32 species given in Table 1 is not a complete list for the site. Many other species are known to be present but a large proportion are cryptic, the workers foraging mainly within soil and the litter layer. Therefore they are, in general, not susceptible to pitfall trapping and only three cryptic species were recorded in these traps: *Amblyopone australis** and the *Heteroponera* and *Sphinctomyrmex* species. The *Amblyopone* was

trapped frequently and in substantial numbers, suggesting an unsuspected amount of foraging activity on the soil surface. All other species are epigaeic, that is active on the soil surface and, very often, on vegetation. All but one or two, of these nest in soil. One exception is *Iridomyrmex* sp.1 which nests above the ground in hollow eucalypt branches and *Iridomyrmex* sp.4 may nest arboreally as well since I know it only, as in this case, from alate queens. This combination of cryptic and soil- and arboreal-nesting epigaeic ants is typical of communities of forests and woodlands in the wetter parts of South Australia (Greenslade, in press).

Seasonal trends in captures of the cryptic species (Fig. 1a) are broadly consistent with the pattern already noted for ants extracted from soil and litter samples. Together, the epigaeic species showed a simple summer maximum (Fig. 1b), although there are differences between the two transects. On the well insolated northwest-facing slope activity, as indicated by pitfall captures, extended throughout the summer (Fig. 1c); on the shaded southwestern slope catches fell from December onwards (Fig. 1d).
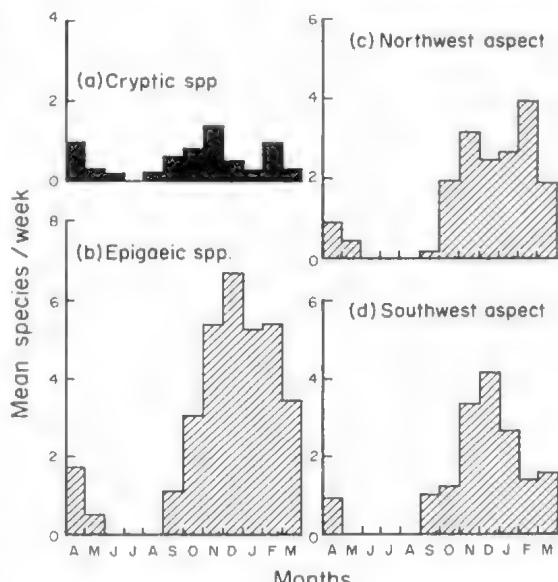
Fig. 1. Mean weekly catches: (a) cryptic species; (b) other, epigaeic species; (c) epigaeic species, northwest aspect; (d) epigaeic species, southwest aspect.

This is contrary to expectation. From other studies (Greenslade 1975, in press) it might be predicted that catches on the northwest slope would increase earlier in the spring than on the southwest slope, only to decline sooner in the late summer as the habitat became excessively hot and dry, inhibiting foraging. It remains possible that this applies to

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*For the few species for which specific names are available, authorities are given in Table 1. Numbers within genera refer only to this site. Voucher speciments are retained in my collection pending further studies and are to be deposited in the Australian National Insect, CSIRO, Division of Entomology, Canberra.

TABLE 1. *Ants trapped at Bridgewater 1983-84. Total records on slopes with northwest and southwest aspects. South Australian distribution: W, occurring only in the wettest, most humid parts of the State; D, occurring mainly in areas drier than this Bridgewater locality; M, at about the midpoint of their range on the rainfall gradient at Bridgewater.*

Ant Species	South Australian distribution	Northwest aspect	Southwest aspect	Total
Myrmeciinae				
Myrmecia nigriscapa Roger	W	—	2	2
M. forficata (Fabricius)	W	—	4	4
M. pyriformis F. Smith	D	4	2	6
M. pilosula F. Smith	M	6	6	12
Ponerinae				
Amblyopone australis Erichson	M	12	17	29
Heteroponera imbellis (Emery)	D	—	1	1
Rhytidoponera 'metallica' (F. Smith)	D	3	—	3
Sphinctomyrmex sp.	M	—	1	1
Myrmicinae				
Epopostruma sp.	M	—	1	1
Crematogaster sp.1	W	1	7	8
Crematogaster sp.2	D	2	1	3
Meranoplus sp.	D	1	—	1
Pheidole sp.1	W	2	17	19
Pheidole sp.2	D	6	1	7
Chelaner sp.1	W	—	5	5
Chelaner sp.2	M	—	2	2
Chalaner sp.3	?	1	—	1
Gen et sp. indet.*	?	1	—	1
Dolichoderinae				
Iridomyrmex purpureus (F. Smith)	D	2	—	2
Iridomyrmex sp.1	W	10	15	25
Iridomyrmex sp.2	D	3	1	4
Iridomyrmex sp.3	D	2	1	3
Iridomyrmex sp.4	D	1	—	1
Dolichoderus sp.	D	5	1	6
Formicinae				
Melophorus sp.1	D	1	—	1
Melophorus sp.2	D	1	—	1
Notoncus sp.	D	2	—	2
Camponotus suffusus F. Smith	M	—	1	1
C. 'consobrinus' Erichson	D	18	2	20
C. innexus Forel	D	3	—	3
Camponotus sp.2	?	1	—	1
Camponotus sp.3	?	—	1	1
Total				
Species		23	21	32
Records		88	89	177

*A damaged alate queen

some species but can be tested only for those that were relatively frequent in both transects, i.e. *Myrmecia pilosula, Amblyopone australis* and *Iridomyrmex* sp.1. In neither transect however do the summed frequencies of these species differ significantly from the overall trend for the whole fauna with both transects combined: northwest $x^2_{(11)} = 4.60$, $p > 0.05$; southwest, $x^2_{(11)} = 3.95$, $p > 0.05$. The differences between Figures 1c and 1d therefore indicate that the two sets of traps sampled different combinations of species, i.e. different communities.

All but four of the species in Table 1 can be placed in one or other of three groups according to their known distributions in relation to rainfall in South Australia (from material in my collection and that of the South Australian Museum). These groups are defined in the caption to Table 1 which compares transects. Treated as a contingency table this shows significant heterogeneity. Group W predominates in catches on the southwest slope, group D on the northwest slope; the community here seems the best adapted to exploiting high summer temperatures and withstanding dry conditions (Table 2).

The phenology of the epigaeic members of groups D, M and W is shown in Fig. 2 where catches from both transects are combined. Compared with group D, group W is active earlier in the spring and has an earlier maximum; catches decline through

TABLE 2. *Catches in the two transects with species grouped according to their distributions in relation to rainfall in South Australia:* W, D, M,—see legend to Table 1 for explanation.

Transect	Distribution type			Totals
	W	M	D	
Northwest	13	18	54	85
Southwest	50	27	10	87
Totals	63	45	64	172
$\chi^2_{[2]} = 55.4$			$P \ll 0.001$	

the summer but extend further into the autumn. Group M is essentially a single species, *Myrmecia pilosula* (see Table 1), whose seasonal distribution in traps is closer to group D than group W.
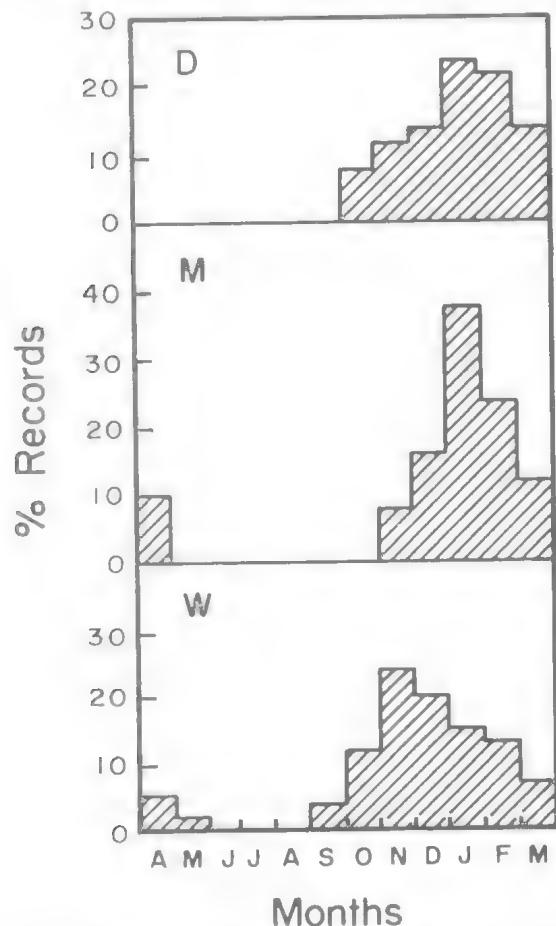
Fig. 2. Seasonal occurrence of epigaeic ant species according to their South Australian distributions. See caption to Table 1 for explanation of distribution types D, M, W.

Table 3 describes the ants in each transect in terms of their biogeographical distributions and their role and status in communities. Here, distribution refers to the Australia-wide range of genera and species groups and not, as in Table 2, to the South Australian distribution of individual species. 'Role and Status', is explained in detail by Greenslade (in press).

Taking the biogeographical affinities of these communities first, there is only a small element of species belonging to Eyrean groups, centred on arid Australia, and it is most evident on the northwest slope. Conversely, Bassian taxa, characteristic of cool southern and highland climates, are best developed on the southwestern slope.

Turning to community structure, there are biologically significant differences between transects in most rows in Table 3. The majority of Australian ant communities share a basic framework of epigaeic soil-nesting species consisting of dominant *Iridomyrmex* species (row 1a in Table 3), subordinate formicines, typically members of the genus *Camponotus* (row 2), and species of *Melophorus* that forage when most other ants are inactive (in row 3a) (Greenslade 1979). Commonly accompanying these genera are broadly adapted, opportunist species of the *Rhytidoponera 'metallica'* complex. As the frequency of cryptic and arboreal-nesting species increases in more humid climates, this *Iridomyrmex*-dominated core becomes less important, as can be seen here. *Iridomyrmex, Camponotus, Melophorus* and *R. 'metallica'* contributed about half the total catches in the northwestern transect with 45 records of 11 species (Tables 1, 3). On the southwest slope the incidence of these genera was halved: 21 records of only six species. To compensate, on the southwest slope there was an increase in catches of cryptic ants and of ground-living *Pheidole* and *Crematogaster* species (in rows 4 and 5 in Table 3): 45 records of seven species compared with 23 records of five species on the northwest slope.

This northwest-southwest difference is illustrated further by comparing the Bridgewater communities with the results of pitfall-trapping on Wilson's Promontory in southern Victoria. Here A. N. Andersen (unpubl. ms) sampled ants in *Casuarina-Leptospermum* heath and adjacent *Eucalyptus*

TABLE 3. *Structure of ant communities at Bridgewater. Taxa (genera and species groups) are classed according to their biogeographical distributions and role and status in communities. Role and status is described in detail by Greenslade (in press). Dashes (–) indicate cells that are unoccupiable or apparently have no occupants in the Australian ant fauna; e.g. cell C3 is unoccupiable: it is not possible to have a 'climate specialist' that is widely distributed in respect to climate. A fourth distributional category 'Torresian' (i.e. northern tropical) is recognised but it is not represented by any species in these communities so the fourth column has been omitted. Fractions indicate number of species/number of records.*

Role and Status	Biogeographical distribution						Totals	
	A Eyrean		B Bassian		C Widely distributed			
	Northwest aspect	Southwest aspect	Northwest aspect	Southwest aspect	Northwest aspect	Southwest aspect	Northwest aspect	Southwest aspect
1 Dominant Dolichoderinae a. *Iridomyrmex*	2/5 *Iridomyrmex*	1/1 *Iridomyrmex*	1/10 *Iridomyrmex*	1/15	2/3 *Iridomyrmex*	1/1	5/18	3/17
b. Other genera	—		1/5 *Dolichoderus*	1/1		nil	1/5	1/1
2 Subordinate camponotine Formicinae	nil		nil		3/22 *Camponotus*	3/4	3/22	3/4
3 Climate specialists	3/3 *Meranoplus* *Melophorus*	0/0	2/3 *Epopostruma* *Chelaner* *Notoncus*	3/8		—	5/6	3/8
4 Cryptic and/or predacious on micro-arthropods	—		1/12 *Amblyopone*	1/17	0/0 *Heteroponera* *Sphinctomyrmex*	2/2	1/12	3/19
5 Generalised myrmicines	—		—		4/11 *Crematogaster* *Pheidole*	4/26	4/11	4/26
6 Opportunists	—		nil *Rhytidoponera*		1/3	0/0	1/3	0/0
7 Large solitary foragers	nil		2/10 *Myrmecia*	4/14	nil		2/10	4/14
Totals	5/8	1/1	7/40	10/55	10/39	10/33	22/87	21/89

baxteri woodland. Rainfall was similar to that at Bridgewater, c.1000 mm per annum, but evenly distributed through the year. Although the soil, a siliceous sand, also differs there are similarities in ant faunas. Among *Myrmecia* for example, *M. pyriformis*, *M. nigriscapa* and *M. pilosula* were all trapped at Wilson's Promontory (compare Table 1).

Andersen partitioned his communities according to the structure in Table 3. Using his raw data, Wilson's Promontory—Bridgewater ants can be compared by means of a correlation coefficient where the occupiable cells in Table 3 provide 21 paired observations (Table 4). At Wilson's Promontory, as at Bridgewater, there were no

TABLE 4. *Comparison of the structure of ant communities at Bridgewater, South Australia, and Wilson's Promontory, Victoria (see text). Correlation coefficients (r) for frequencies in pairs of communities partitioned as in Table 3. Significance: *, **, ***, p <0.05, < 0.01, < 0.001.*

Localities and habitats		Bridgewater		Wilson's Promontory
		Northwest aspect	Southwest aspect	Woodland
Wilsons' Promontory	Heath	0.30	0.40	0.55
	Woodland	0.17	0.51*	
Bridgewater	Southwest aspect	0.70*		

Torresian taxa so the fourth column is omitted. The closest similarities were between adjacent habitats at both localities (Table 4), in each case due to a large proportion (42%) of shared species: Bridgewater 13/31 (Table 1), Wilson's Promontory 14/33. The heath community differed from both Bridgewater communities and this can be related to differences in vegetation structure and composition. However there is a statistically significant correlation between ant communities in woodland at Wilson's Promontory and in the cool, shaded, southwest facing transect at Bridgewater. In contrast, emphasising the difference in structure of the two Bridgewater ant communities, and despite the number of species they share there is little similarity in structure between the northwest-facing transect and Wilson's Promontory woodland.

Discussion

These results from pitfall traps conform with other phenological observations on ants in the Mt Lofty Ranges (Greenslade 1975, Greenslade & Greenslade 1983), showing a pronounced summer maximum in catches of epigaeic species and greatly reduced activity in the winter. The same seasonal trends have been described for ants taken in pitfall traps in similar mediterranean climates in Western Australia (Majer 1978, 1980).

Different ant species have different ranges on rainfall gradients in South Australia, giving complex overlapping patterns of distribution and associations of species. Consequently the change from communities of predominantly epigaeic, soil-nesting ants, dominated by *Iridomyrmex* in dry areas, to weakened *Iridomyrmex*-dominance and stratification of cryptic, soil-nesting and arboreal epigaeic species in wetter climates is essentially a continuum. But differences between these two transects suggest that there may be critical points on this continuum.

Iridomyrmex purpureus is not found in the highest parts of the Mt Lofty Ranges which reach 700 m above sea level. *Myrmecia forficata* does occur here but not *M. pyriformis*. At a lower elevation in the ranges, at 300 m at Belair, a population of *I. purpureus* was studied in *Eucalyptus leucoxylon-E. odorata* woodland (Greenslade 1975). Here it occurred with *Myrmecia pyriformis*, as on the northwestern slope at Bridgewater. A further Belair ant community has been investigated recently (O'Dowd, in press) at 445 m with *E. obliqua* (one of the species at Bridgewater): *M. forficata* is present but *M. pyriformis* and *I. purpureus* are not. At 350 m the Bridgewater ant fauna seems to be transitional; it contains both *Myrmecia* species as well as *I. purpureus* which must be close to its cool, wet limit since nests are restricted to open, sunny situations on and near a track.

The same switch from *I. purpureus* and *M. pyriformis*, to *M. forficata* without *I. purpureus* is to be seen on Kangaroo Island. The first pair of species occur at the drier eastern end of the island while *M. forficata* alone is found in the moister maritime climate to the west (Greenslade 1976, in press). The two *Myrmecia* species show similar relative distribution patterns in relation to environmental moisture in southern Victoria (A. N. Andersen, pers. comm.

The Bridgewater ant communities have further significance in the context of conservation and environmental assessment. Greenslade & Greenslade (1984) suggested that terrestrial invertebrates should not be ignored in this field since they may integrate environmental variables in ways quite different from plant associations. Consequently it cannot be assumed that a vegetation type supports one characteristic invertebrate community, and invertebrate distributions may lead to insight into critical factors in an environment. The differences between ant communities of the two Bridgewater transects are a good example since they exist within a single floristic and structural vegetation type and they demonstrate the importance of aspect.

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SPIRURA AURANGABADENSIS (ALI & LOVEKAR) (NEMATODA: SPIRURIDAE) FROM SMALL DASYURIDAE (MARSUPIALIA)

BY DAVID M. SPRATT

Summary

Spirura aurangabadensis (Ali & Lovekar, 1967) Quentin & Krishnasamy, 1975 is described from the oesophageal mucosa of the dasyurid marsupials Antechinus stuartti Macleay, Planigale ingrami (Thomas) and Sminthopsis leucopus (Gray). This is the first member of the genus reported from Australian native mammals, although the species has been described from a microchiropteran (Taphozous kachhensis Dobson) in India and from tupaiid (Tupaia glis (Diard)) and lorisid (Nycticebus coucang (Boddaert)) primates in Malaysia.

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Summary

SPRATT, D. M. (1985) *Spirura aurangabadensis* (Ali & Lovekar) (Nematoda: Spiruridae) from small Dasyuridae (Marsupialia). *Trans. R. Soc. S. Aust.* 109(1), 25-29, 28 June, 1985.

Spirura aurangabadensis (Ali & Lovekar, 1967) Quentin & Krishnasamy, 1975 is described from the oesophageal mucosa of the dasyurid marsupials *Antechinus stuartii* Macleay, *Planigale ingrami* (Thomas) and *Sminthopsis leucopus* (Gray). This is the first member of the genus reported from Australian native mammals, although the species has been described from a microchiropteran (*Taphozous kachhensis* Dobson) in India and from tupaiid (*Tupaia glis* (Diard)) and lorisid (*Nycticebus coucang* (Boddaert)) primates in Malaysia.

S. aurangabadensis is similar in morphology and in host distribution to *S. guianensis* (Ortlepp, 1924) Chitwood, 1938 from platyrrhine primates and didelphid marsupials in South America. Cephalic structures in third-stage larvae of *S. aurangabadensis* from *A. stuartii* are, in contrast to larvae of *S. guianensis*, identical to those in adult forms, offering further evidence that *S. guianensis* is the more highly evolved member of the genus. Although the genus *Spirura* is probably of Gondwanaland origin, it is unlikely that *S. aurangabadensis* entered Australia via this route, but rather from the north with Chiroptera or with windborne Insecta. Its occurrence in Australian marsupials is interpreted as secondary transfer.

KEY WORDS: *Spirura*, Nematoda, distribution, hosts, morphology, Dasyuridae.

Introduction

The spiruroid nematodes of Australasian marsupials are in need of a thorough taxonomic revision. A preliminary assessment of the group, based on examination of type specimens held in Australian institutions and on material collected since 1967, revealed that one species exhibited morphological relationships more akin to those from a microchiropteran, primates and didelphid marsupials than to those from other Australasian marsupials. Details of this parasite, from the small dasyurid marsupials *Antechinus stuartii* Macleay, *Planigale ingrami* (Thomas) and *Sminthopsis leucopus* (Gray) form the basis of this report.

Materials and Methods

Native mammals were examined during the period March 1967–December 1983 from the following regions: Arnhem Land, Northern Territory; Queensland; southeastern New South Wales; northeastern Victoria, the Australian Capital Territory; northern Tasmania.

Nematodes recovered by the author were fixed in hot, 10% neutral buffered formalin and cleared in lactophenol.

The following abbreviations for morphological features of adult worms and third-stage larvae are used in the text:

L Length of body, MW Maximum width of body, P Length × width of pharynx, NR Length from cephalic extremity to nerve ring, EP Length from cephalic extremity to excretory pore, D Length from cephalic extremity to deirids, MO Length of muscular oesophagus, GO Length of glandular oesophagus, TO Total length of oesophagus, VCB Length from cephalic extremity to ventral cuticular boss (large thumb-like swelling on ventral surface of body), V Length from cephalic extremity to vulva, RS Length of right spicule, LS Length of left spicule, T Length from caudal extremity to anus or cloaca, GP Length from cephalic extremity to genital primordium of third-stage larva

Measurements were made with the aid of an ocular micrometer, drawing tube, and measuring wheel, and are presented in micrometers unless otherwise stated. The range of measurements is followed by the mean, in parentheses. Illustrations were made with the aid of a Leitz drawing device.

Specimens have been deposited in the Australian Helminthological Collection (AHC), Queensland Museum (QM), South Australian Museum (SAM), United States National Museum Helminthological Collection (USNMHC) and Division of Wildlife & Rangelands Research, CSIRO (WL HC).

Results

A characteristic spiruroid nematode was encountered rarely, attached to the oesophageal mucosa of small dasyurid marsupials. Number of hosts infected/number of hosts examined from each locality are shown in parentheses. The parasite was found in *Antechinus stuartii* at Mt Nebo (1/5), Qld, and in the same host at Nadgee Nature Reserve

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(section formerly part of Nadgee State Forest) (6/54), N.S.W., in the same host at Jervis Bay (2/28), A.C.T., in *Sminthopsis leucopus* at Timbillica State Forest (1/9), N.S.W., and in *Planigale ingrami* at the Smithburne River (1/2), near the Gulf of Carpentaria, Qld.

In view of the taxonomic complexity suspected in the nominal species *A. stuartii,* collection details of specimens from this host from different geographical localities are presented separately.

Spirura aurangabadensis (Ali & Lovekar, 1967) FIGS 1-11

Material examined: from *Antechinus stuartii,* Nadgee Nature Reserve, near Eden, N.S.W., P. Haycock and E. Walter, 1♂, 1♀, 3.xii.1981 in WL HC N1438; 1♀, 5.iii.1982 in WL HC N1519; 1♂ posterior, 7.vi.1982 in WL HC N1630; 1♂, 1♀ anterior, 2♀♀ posterior, 8.iii.1982 in AHC No. 13651; 1♂, 1♀, 7.vi.1982 and 1♀ 10.iv.1984 in SAM Nos. V3557, V3558, V3559.

From *A. stuartii,* Jervis Bay, coastal A.C.T., J. Kenagy and P. Haycock, 1♂, 1♀, 12.ix.1983 in USNMHC No. 78252; 1♂, 2 L₃, 7.xii.1983 in AHC No. 13652.

From *A. stuartii,* Mt Nebo, Qld, D. M. Spratt, 1♂, 1♀ anterior, 19.vii.1973 in WL HC N167.

From *Sminthopsis leucopus,* Timbillica State Forest, near Eden, N.S.W., E. Walter and P. Haycock, 1♂, 1♀, 1.xii.1983 in AHC No. 13653.

From *Planigale ingrami,* Smithburne River, near Normanton, Qld, L. Owens, 1♀, 4.i.1979 in QM No. GL 4613.

Description

Short, robust nematodes, attenuated anteriorly and generally reflexed in anterior ¼ or ⅓ of body. Both sexes bearing large, thumb-like swelling on ventral surface of body (ventral cuticular boss) at point of reflection; threads of host connective tissue and infiltrating cells passing under ventral cuticular boss and surrounding body of nematode at this point, boss apparently serving as holdfast for nematode in lumen of oesophagus. Cuticle thick, deeply wrinkled or folded anteriorly, with prominent transverse striations throughout. Cephalic region with prominent elevated cuticular shield or plate formed as extension of cuticle of pharynx and hiding inner circle of cephalic papillae and amphids in *en face* view (Fig. 1). Pharynx large, laterally compressed, indistinctly divided into two parts, armed with six robust teeth originating at base and protruding well beyond oral opening. Teeth simple and non-bifid at distal extremities, terminating in smooth, sharp points. Teeth indented on non-oral margin when viewed in transverse section at level of oral opening; oral opening dorso-ventrally elongated, with large lateral pseudolabia (Fig. 2). Four pairs submedian cephalic papillae arranged in inner circle of four large and outer circle of four smaller papillae. Amphids large, opening at base of elevated lateral pseudolabia. Oesophagus

divided into short muscular anterior and long glandular posterior regions, terminating in short but distinct valvular region (Fig. 7). Nerve ring near junction of muscular and glandular oesophagus. Large conspicuous deirids anterior to nerve ring. Excretory pore observed in only two specimens, near level of deirids in male, well posterior to nerve ring in female.

Measurements

Male (7 complete specimens, 1 anterior end): L 5.4-8.5 (6.5) mm; MW 180-390 (294); P 50×30-80×50 (60×40); NR 160-275 (232); EP 110 (observed in one specimen only); D 120-170 (146); VCB 1180-1770 (1572); MO 170-300 (242); GO 2380-4620 (2986); TO 2600-4920 (3218). Spicules unequal, dissimilar, RS 170-230 (208) and LS 488-612 (545) in length (Fig. 11). Gubernaculum boat-shaped, narrowed distally, broad proximally with in-rolled lateral edges, 80 in length (Fig. 6). T 124-240 (193), with narrow caudal alae but without cuticular bosses on ventral surface. Generally four pairs large pre-cloacal papillae (Fig. 5) (one specimen with three papillae on right side, four papillae on left side); two pairs large post-cloacal papillae, one pair immediately posterior to cloaca, one pair near tail tip (Fig. 9); single, small, median papilla near tail tip and pair of minute subterminal phasmids.

Female (8 complete specimens, 1 anterior end, 2 posterior ends (Fig. 8)): L 7.9-15.4 (10.9) mm; MW 312-645 (445); P 60×30-90×60 (75×43); NR 170-370 (243); EP 412 (observed in one specimen only); D 100-200 (157); VCB 1690-3150 (2174); MO 230-350 (268); GO 3052-6010 (3822); TO 3332-6360 (4090). Proximal vagina with thick cuticular lining, surrounded by thick muscular wall and convoluted distally, V 3518-5460 (4055), vulval opening surrounded by small, irregular, densely-packed cuticular bosses (Fig. 10). T 120-240 (174), terminating in three minute cuticular digits. Eggs in distal vagina 34×25-40×30 (38×27), containing larviform embryos.

Third-stage larva (2 complete specimens): Small ventral cuticular boss present in anterior one-third of body (Fig. 4). Cuticle thick, with prominent transverse striations throughout length. Cephalic region as in adults (Fig. 3). Pharynx similar to that in adults, however teeth less sclerotised, walls thinner and clearly divided into anterior and posterior parts. Oesophagus divided into short anterior muscular and very long posterior glandular regions. Nerve ring in anterior region of muscular oesophagus. Excretory pore conspicuous, opening into elongate, terminal excretory duct. Subventral glands conspicuous, each with prominent nucleus and
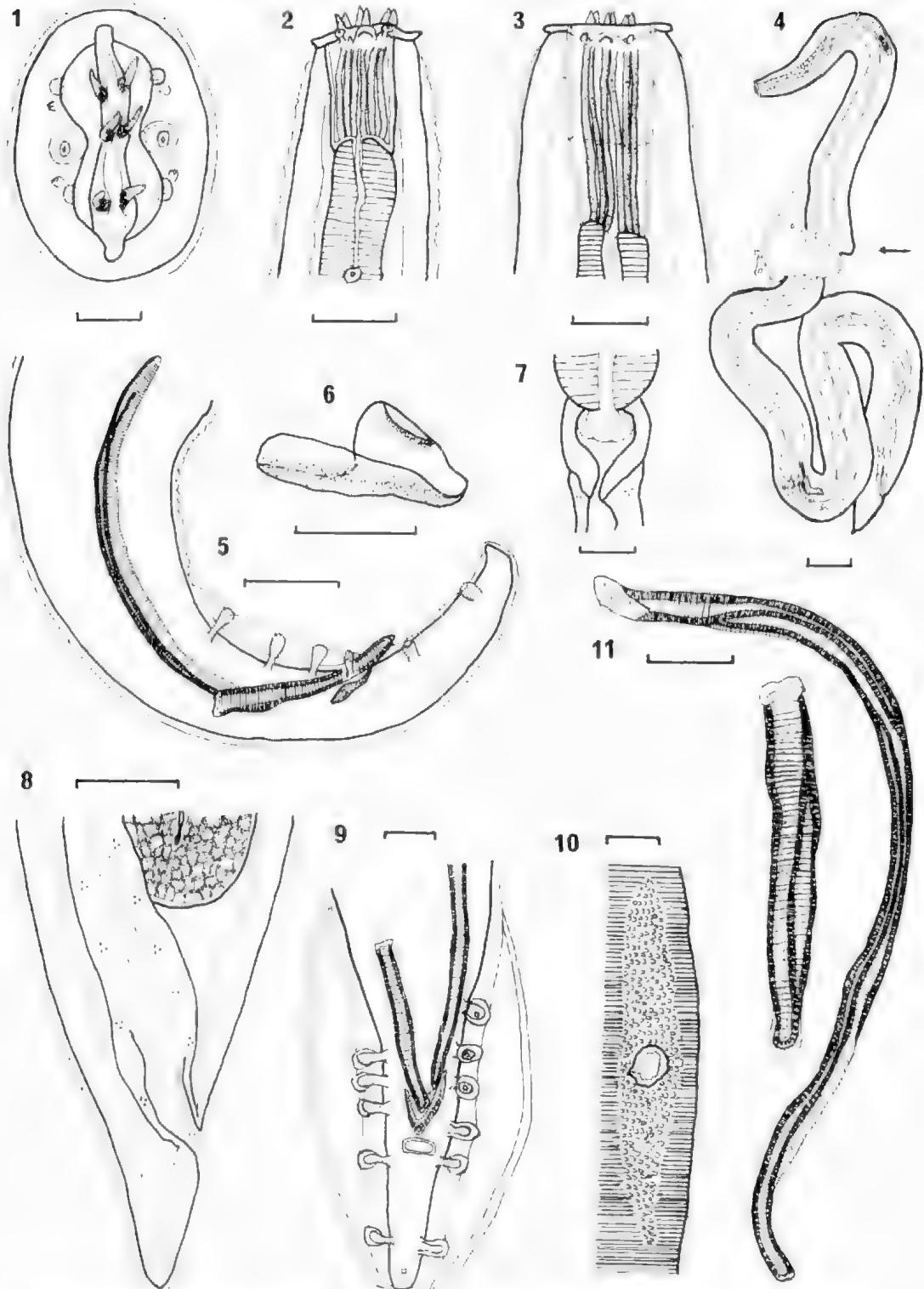
Figs 1-11. *Spirura aurangabadensis* from small dasyurid marsupials. 1 Cephalic end, adult, *en face* view. 2. Cephalic end, adult, lateral view. 3. Cephalic end, third-stage larva, lateral view. 4. Third-stage larva, lateral view (arrow — ventral cuticular boss). 5. Caudal end male, lateral view. 6. Gubernaculum, latero-ventral view. 7 Oesophago-intestinal junction, lateral view. 8. Caudal end female, lateral view. 9. Caudal end male, ventral view. 10. Cuticular bosses around vulval opening. 11. Right and left spicules, ventral and latero-ventral views respectively. Scale lines: Figs 1, 3, 20 μm; Figs 2, 6, 9-11, 50 μm; Figs 4, 5, 7, 100 μm.

nucleolus. Deirids slightly anterior to nerve ring. Genital primordium small, just anterior to oesophago-intestinal junction in one specimen, extending anterior and posterior from junction in other specimen. Tail terminating in single papilliform structure. Lateral alae absent.

L 2.55, 2.47 (2.51) mm; MW 97, 113 (105); P 46×24, 45×20 (46×22);NR 120, 96 (108); EP 310, 270 (290); D 105, 92 (98); VCB 813, 738 (776); MO 154, 157 (156); GO 1482, 1198 (1340); TO 1616, 1354 (1485); GP 1510, 1150 (1330); T 85, 96 (91).

Discussion

The laterally compressed pharynx, dorso-ventrally elongated oral opening with large lateral pseudolabia and the ventral cuticular boss in both sexes are characteristic of the nematode genus *Spirura* (Spiruridae). Cephalic, cuticular and genital structures in specimens from small dasyurids in Australia are unique among members of the genus *Spirura* and are identical to those occurring in *S. aurangabadensis* originally described from a microchiropteran (*Taphozous kachhensis* Dobson) in India (Ali & Lovekar, 1967) and redescribed from tupaiid and lorisid primates (*Tupaia glis* (Diard) and *Nycticebus coucang* (Boddaert)) in Malaysia (Quentin & Krishnasamy, 1975).

Specimens, particularly males, from Australian hosts are similar in size to those from *T. kachhensis* but generally smaller in all measurements than those from primates. However, my measurements and those of Quentin & Krishnasamy (1975) indicate that this is due, at least in part, to the age and/or state of maturity of the nematodes and does not justify erection of a new species for the Australian material. In all other respects except one (males with two pairs post-cloacal papillae and single median subterminal papilla *contra* males with three pairs post-cloacal papillae) specimens from Australian hosts are identical with those from Indian and Malaysian hosts and are here recognised as conspecific and determined as *S. aurangabadensis* (Ali & Lovekar, 1967) Quentin & Krishnasamy, 1975.

Spirura aurangabadensis is distinguished from all species of *Spirura* except *S. guianensis* (Ortlepp, 1924) Chitwood, 1938 (syn. *S. tamarini* Cosgrove, Nelson & Jones, 1963) by the presence in both sexes of six robust teeth originating at the base of the pharynx and protruding well beyond the oral opening, and the presence of a cuticular cephalic plate or shield formed from an oral extension and outfolding of the cuticular wall of the pharynx, and hiding the inner circle of cephalic papillae and amphids in *en face* view.

These two features serve also to distinguish *S. guianensis* from the other 19 species of the genus recognised by Quentin (1979). The similarities between *S. aurangabadensis* from microchiropteran, primate and dasyurid marsupial hosts in India, Malaysia and Australia and *S. guianensis* from the oesophagus of platyrrhine primates of the genus *Saguinus* in South America (Ortlepp, 1924; Cosgrove *et al.* 1963; Thatcher & Porter, 1968) and from the same site in the didelphid marsupials *Caluromys philander* (L.), *Marmosa cinerea amarare* Thomas and *Philander (Metachirops) opossum* (L.) in Guiana (Quentin, 1973), are striking.

Nevertheless, *S. aurangabadensis* is readily distinguished from *S. guianensis* by the following suite of characters: (i) pharyngeal teeth terminating distally in uniformly tapered, sharp points rather than a bifid extremity, (ii) absence of five ventral cuticular denticles on cephalic plate, (iii) cephalic papillae of inner circle larger than those of outer circle, (iv) presence of fine cuticular bosses surrounding vulva, (v) absence of longitudinal cuticular bosses on ventral surface of male tail, and (vi) much longer (2×) and morphologically distinct left spicule.

On the basis of host distribution and comparative study of larval and adult cephalic structures it was postulated that the genus *Spirura* originated in lemurids in Madagascar and Africa and that it diversified principally along two evolutionary pathways in Old World host groups which first appear in the palaeontological record during the Tertiary (Quentin & Krishnasamy, 1975; Quentin, 1979). In the most primitive line the border of the cephalic cuticular collarette is rounded in dorsal and ventral regions in both larval and adult forms. Cephalic structures remain stable and five groups containing 17 species are recognised (Quentin, 1979). Evolution among these groups of species is based principally on differentiation of genital features in male worms.

In the more advanced line the border of the cephalic cuticular collarette is drawn out into dorsal and ventral points at least in the infective larval stage. In the four species recognised in this group cephalic structures are not stable and in the most specialised form, *S. guianensis,* structures in infective larvae are distinct from those in fourth-stage larvae and adult forms (Quentin, 1973) and similar to structures seen in adults of less specialised members of the line (Quentin & Krishnasamy, 1975; Quentin, 1979). Third-stage larvae of *S. aurangabadensis* in *A. stuartii* exhibit cephalic features similar to those in adults and to those in third-stage larvae of *S. guianensis,* supporting the

argument that *S. guianensis* is the more highly evolved member of the second line (Quentin & Krishnasamy, 1975; Quentin, 1979).

These authors argued that the occurrence of the most highly differentiated form, *S. guianensis,* in South America was due to its geographical isolation in ancient platyrrhine primates. Its presence in neotropical marsupials was attributed to secondary invasion of ecological causation. The occurrence of *S. aurangabadensis* in Australian marsupials is interpreted also as a consequence of secondary transfer. The less specialised form of cephalic structures occurring in third-stage larvae and adult forms suggests that the species has not undergone lengthy geographic isolation in marsupials in Australia. On the contrary, although the genus *Spirura* is probably of Gondwanaland origin it is unlikely that *S. aurangabadensis* entered Australia via this route, but rather from the north with Chiroptera, or with windborne Insecta (e.g. *Locusta* sp.) which probably serve as natural intermediate host of the parasite.

Acknowledgments

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GROWTH IN CAPTIVE BORN TIGER SNAKES (NOTECHIS ATER SERVENTYI) FROM CHAPPELL ISLAND: IMPLICATIONS FOR FIELD AND LABORATORY STUDIES

BY B. BARNETT & T. D. SCHWANER

Summary

Captive born tiger snakes (Notechis ater serventyi) from Chappell Island, Bass Strait were fed house mice ad libitum. Growth rates (total length and weight) were twice that of mainland tiger snakes and 5-10 times that of natural populations on other islands. The pattern of increase in weight was exponential during the first six months of the study. Growth in length for the first six months was best explained by a linear model; both linear and logarithimic models explained growth in length during the second six months. Regression analysis detected a significantly greater increase in length relative to weight in the first six months of growth, but increase in weight relative to length during the second six months of growth. An estimate of gross growth efficiency indicated that metabolic rate was relatively constant for these snakes under prescribed conditions. Patterns of growth measured under controlled conditions may provide an insight into the evolution of life history traits in natural populations of tiger snakes.

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by B. Barnett* & T. D. Schwaner†

Summary

Barnett, B. & Schwaner, T. D. (1985) Growth in captive born tiger snakes *(Notechis ater serventyi)* from Chappell Island: implications for field and laboratory studies. *Trans. R. Soc. S. Aust.* 109(2), 31-36, 28 June, 1985.

Captive born tiger snakes *(Notechis ater serventyi)* from Chappell Island, Bass Strait were fed house mice *ad libitum*. Growth rates (total length and weight) were twice that of mainland tiger snakes and 5–10 times that of natural populations on other islands. The pattern of increase in weight was exponential during the first six months and linear during the second six months of the study. Growth in length for the first six months was best explained by a linear model; both linear and logarithmic models explained growth in length during the second six months. Regression analysis detected a significantly greater increase in length relative to weight in the first six months of growth, but increase in weight relative to length during the second six months of growth. An estimate of gross growth efficiency indicated that metabolic rate was relatively constant for these snakes under prescribed conditions. Patterns of growth measured under controlled conditions may provide an insight into the evolution of life history traits in natural populations of tiger snakes.

KEY WORDS: Snakes, growth, captive husbandry, *Notechis ater serventyi*.

Introduction

Chappell Island, Bass Strait supports a population of tiger snakes *(Notechis ater serventyi)* in which individuals reach adult body lengths approaching 2 m (Worrell 1958). The great size attained is almost twice the average length of individuals on the mainland (Shine 1978), and is rivalled only by a few other island populations of tiger snakes in Bass Strait and the Nuyts Archipelago, South Australia. Although large adult size in these snakes has been attributed to their habit of eating muttonbirds (Worrell 1958), no data exist to quantify their feeding habits or to determine growth patterns from birth to adulthood. The only previous studies of growth and maturation in tiger snakes involved dissection of museum specimens or estimates of these parameters from field sampling of the mainland species, *N. scutatus* (Shine 1978).

Here we report a one year study of feeding and growth in a brood of new-born, captive tiger snakes from Chappell Island. The results are compared with previous studies of growth rates in tiger snakes, and with recent (unpublished) evidence for growth in a population of marked tiger snakes on the Franklin Islands in S. Aust.

Materials and Methods

A subset of six snakes was taken from a brood of 31 neonates born to a captive Chappell Island tiger snake of 1420 mm total length, on 3.iii.83.

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Selection of the subset was biased by the need to pair different colour morphs for individual identification in cages, and to achieve equal representation of sexes. However, comparisons of individual weights and total body lengths with those of the brood means for these parameters satisfied the null hypothesis that each individual was sampled from the same statistical population (t[.05,df=30] = 2.042; t₅ weight = 0.46 − 1.231; t₅ length = 0.49 − 0.68; Sokal & Rohlf 1981).

The six neonates were maintained in pairs in three particle board cages measuring 460 × 480 × 450 mm. The lid of each unit contained a glass window measuring 420 × 250 mm. Light was provided only from 'True-life' fluorescent tubes suspended above the cages. Each cage was fitted with a blue, 40 watt, incandescent light bulb controlled by a thermostat to maintain a constant temperature range of 28–30 °C. Relative humidity was 70% throughout the study.

Snakes were fed entirely on house mice *(Mus musculus)*. Neonates accepted day-old mice directly, or mice rubbed with faeces of scincid lizards (their natural prey). Snakes were fed older, larger mice commensurate with increasing body sizes and their ability to consume larger prey. During the 12 month period, the snakes were fed *ad libitum* to the extent that rejection of food indicated repletion. Daily records were kept of the quantity of food accepted.

Snakes were weighed and measured monthly. Prior to weighing snakes were denied food so that monthly weights would be comparable among individuals. This action reduced the feeding time of each snake by 35-40 days over the 12 months. Complete data sets for monthly growth in length,

weight and amount of food consumed are deposited in the Library, South Australian Museum.

Length and weight measurements were examined by least-squares regression to determine a line of best fit to the data, and an equation describing growth was generated. Exponential ($y = ae^{bt}$), linear ($y = a + bt$), and logarithimic ($y = a + b\ln t$) equations were used to generate the best fit to the growth data, where y = length (in mm) or weight (in g), t = age (in months), a = the y intercept, b = the slope and e = the natural logarithim of 2. For each linear regression the largest value of the squared correlation coefficient (r^2) was used as the criterion to determine which equation best fit a given set of data.

Growth rates were determined using the instantaneous coefficient of growth, (G), calculated from the equation:

$$G = \ln Y_2 - \ln Y_1 / t_2 - t_1$$

where Y_1 = initial length or weight, Y_2 = final

length-weight relationships were tested by regression analysis (Sokal & Rohlf 1981).

Gross growth efficiency (GGE) was calculated by dividing the average increase in weight of snakes by the average weight of ingested prey, for a given month, and multiplying by 100.

In these analyses data sets are treated without separate calculations for males and females. This was due to the very low degrees of freedom rendered by such a division of the data, and by the noticeable homogeneity in variance of mean length and weight for all but one individual.

The latter was female No 5, which ate only minimally between months 4–6 but thereafter fed normally and achieved a size similar to other snakes by the end of the study.

Results

Growth in weight: Neonates increased from a mean weight of 8.7 g at birth to 1266.0 g at 12

TABLE 1. *Monthly rate of growth in weight and total length of captive* Notechis ater serventyi.

		Weight					Length				
		Group			Growth	Rates	Group			Growth	Rates
No. snakes	Age (mos)	Mean weight (g)	SD (g)	Range (g)	(%/mo)	(g/mo)	Mean length (mm)	SD (mm)	Range (mm)	(%/mo)	(mm/mo)
6	0	8.67	0.25	8.34- 8.98	—	—	289.7	6.41	280- 298	—	—
6	1	18.85	1.63	17.29- 21.91	77.7	14.6	372.8	12.53	355- 388	25.2	73.1
6	2	52.44	11.97	34.84- 67.48	102.3	53.7	508.0	39.29	446- 549	30.9	157.2
6	3	83.61	22.98	43.11- 106.83	46.6	39.0	611.0	63.95	491- 677	18.5	112.8
6	4	123.68	34.04	61.36- 154.18	39.1	48.4	715.0	79.18	568- 799	15.7	112.4
6	5	196.17	44.04	117.09- 233.03	46.1	90.5	829.8	80.48	681- 914	14.9	123.6
6	6	344.37	72.00	227.76- 430.93	56.3	193.8	949.8	77.29	814-1041	13.5	128.3
6	7	479.74	74.75	336.35- 550.48	33.2	159.0	1040.2	73.88	903-1117	9.1	94.6
6	8	670.69	84.04	503.19- 734.49	33.5	224.7	1137.8	65.17	1017-1205	8.9	102.0
6	9	875.37	104.80	679.42- 968.74	26.6	233.1	1213.6	61.21	1112-1268	6.5	78.3
6	10	1004.70	123.47	774.90-1130.50	13.8	138.4	1270.5	47.21	1186-1308	4.6	58.2
6	11-12	1266.00	153.62	1021.10-1480.10	23.1	292.7	1366.8	45.66	1290-1414	7.3	99.9

length or weight, t_1 = age in months at Y_1 and t_2 = age in months at Y_2 (Forsythe 1984). Relative growth rate was expressed as percentage increase in total length or weight per month, and was calculated by multiplying $G \times 100$. The velocity of growth, or actual increase in any length (L) or weight (W) was calculated as $G \times L$, for rates in mm per month, or $G \times W$, for grams per month (see Forsyth 1984). Differences in slope values for

months (Table 1).

Growth rates were highest during the first six months, with an overall mean rate of increase of 90% for the first two months and 61.4% for the next four months. Growth was exponential during this period and best described by the equation:

$$W(g) = 47.2e^{0.78t}$$

However, correlation coefficients (r) were similar for all models (Table 2; p's > 0.5, Z-test, Zar 1974).

TABLE 2. *Comparison of regression equations for growth in weight and total length of* Notechis ater serventyi. r^2 values are in parentheses.

	Months					
	0-6		6-12		1-12	
Weight	$y = 47.2^{(.78)t}$		(.94)$y = 719.3^{(.004)t}$		(.67)$y = 320.7^{(.006)t}$	(.48)
	$y = -1.4 + 2.21\ln t$		(.75)$y = 564.7 + 210.81\ln t$		(.79)$y = 230.6 + 156t$	(.10)
	$y = -35.3 + 51t$		(.86)$y = -578.6 + 156.3t$		(.98)$y = -190.9 + 110.6t$	(.92)
Length	$y = 435.6^{(3.09)t}$		(.60)$y = 1076^{(.005)t}$		(.69)$y = 758.1^{(.013)t}$	(.38)
	$y = 353.1 + 2.41\ln t$		(.76)$y = 313.6 + 2.81\ln t$		(.99)$y = 224.6 + 6.11\ln t$	(.94)
	$y = 320.5 + 101.6t$		(.99)$y = 498.5 + 78.6t$		(.99)$y = 308.7 + 99.9t$	(.99)

After six months growth rates declined (Table 1) with a mean growth rate of 26.0%/month from the 6th to the 12th month. Growth for all snakes during this latter period was linear and best described by the equation:

$$W(g) = -578.6 + 156t$$

Linear and logarithmic models (Table 2) were similar (p = .09).

Although the percent growth rates (%/mo) generally declined after the first six months, actual mean weight per month (g/mo) increased markedly at this time (Table 1). Monthly increases in actual weight averaged 37.6 g for the first five months; for the last seven months, this increase was 207.0 g. This observation is important for the discussion to follow because the increase in actual weight per month is correlated with a marked increase in feeding rate but not with a similar increase in monthly growth in length (see below).

Growth in length: Neonates increase from a total length of 290 mm at birth to 1367 mm at 12 months (Table 1). Proportional increases in length (%/mo) were highest during the first six months, with an overall mean of 28% for the first two months and 15.6% for the next four months. Thereafter, length increased by an average of only 7.4% per month (Table 1). Unlike proportional weight gains, monthly increases in length were poorly fitted by an exponential curve (Table 2). Variation in monthly length for the first and second six months, respectively, and for the entire study period was explained well however, by logarithmic and particularly, linear growth models (Table 2). Correlation coefficients for all linear models differed significantly (p's <.05) from exponential models (Table 2), but only the linear equation for the first six months differed from the logarithmic model (p <.05).

It is well known that length increases approximately as the cube root of weight (Brody 1945), and that length then must be increasing consistently in proportion to weight. However, the average rate of increase in length for these snakes appeared to be at a much lower rate, proportionally, to the mean increase in weight particularly during the second six months of the study.

Length-weight relationships: The previous analysis suggested two different growth phases for weight and length, one during the first six months and another from six to 12 months. In particular, actual increases in weight (g/mo) were highest during the last seven months, whilst proportional (%/mo) weight gains declined. A similar pattern of decline in proportional growth in length during the last six months also was observed, but actual increases in length (mm/mo) did not differ

markedly throughout the study.

From these observations it would appear that weight increases faster relative to length during the latter six months. This was tested using regression analysis of length versus weight for the two growth phases, months 1-6 and 7-12, respectively. Fig. 1 shows the plotted curves and their equations. The curve for the second six months of growth is steeper than the curve for the first six months, and the regression slopes (3.63 and 2.95, respectively) are highly significantly different (F[1,8]=16.8 p<.005) This difference occurs at a total length of 800-900 mm.
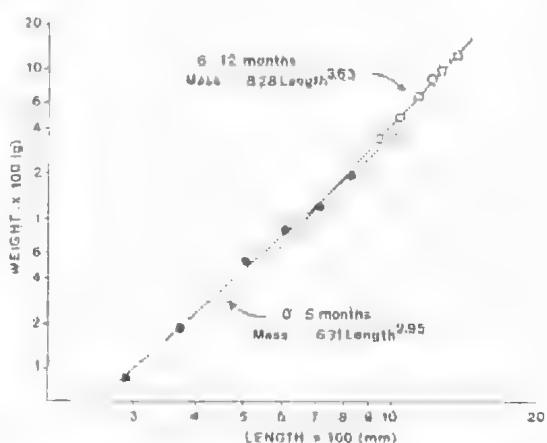
Fig. 1. Log/log plot of length/weight relationship for both growth phases with equations for lines given. Growth phases based on weight increase (g/mo) between months 5-6 (Table 1).

Food Intake: Average weight of food consumed per month varied from 26 g during the first month of the study to 390 g during the last two months. Overall average weight of ingested prey for the first five months was 94 g. However, for the latter six months average consumption of prey rose dramatically to 476 g, five times that for the previous months. This sudden increase in average weight of food consumption coincides precisely with the increase in weight observed at the same time (Table 1; Fig. 1), and occurs at an average total length of about 800-900 mm.

Gross growth efficiency: The overall mean GGE for Chappell Island tiger snakes fed *ad libitum* on mice was 48.6 (SD=9.4). With the exception of the initial feeding interval, GGE was nearly constant over the entire study period. This value compares favourably with similar calculations for other organisms (Forsythe 1984), and suggested that metabolic rate was relatively constant for these snakes under the prescribed conditions.

Discussion

Shine (1978) plotted monthly body lengths and estimated age classes and growth rates of mainland tiger snakes *(Notechis scutatus)* from N.S.W. Both sexes matured in about 24 months at body (snout to vent) lengths of 650 mm (Shine 1978); total length (estimated from a proportion of 16.5% of tail to total length) would be about 760 mm. Growth in length after 14 months was approximately 550 mm SVL (640 mm total length) and the relative rate of increase (adult length/length at birth) was 2.9. Similar values for the captive brood from Chappell Island were 1140 mm SVL (1366 mm total length) and 4.7, respectively. Thus, the Chappell Island brood, when fed *ad libitum,* grew at almost twice the rate of mainland snakes under natural conditions. Furthermore, one pair of the Chappell Island tiger snakes (a male and a female) exhibited courtship and mating behaviour during the 11th month of the study at body sizes of 1116 mm SVL (1337 mm total length) and 1077 mm SVL (1290 mm total length), respectively. Apparently (under laboratory conditions) maturity is reached in Chappell Island tiger snakes at total lengths almost twice that of mainland tiger snakes.

An extensive mark/release/recapture programme for black tiger snakes *(Notechis ater niger)* on West Franklin Island was begun in 1982. Fig. 2 shows SVL classes for snakes when initially marked, and ranges and means for monthly growth in length prior to recapture. The overall average monthly increases in body lengths (SVL) are only 5.5 mm for males and 3.3 mm for females. These estimates lack any pattern of declining growth in adults (SVL vs average growth per month, $r = -0.026$, $n = 51$). The smallest body size for a snake observed in courtship and mating on the Franklin Islands was a female 1002 mm SVL. Given that this size represents adulthood, the mark recapture data suggested that sexual maturity in females could be
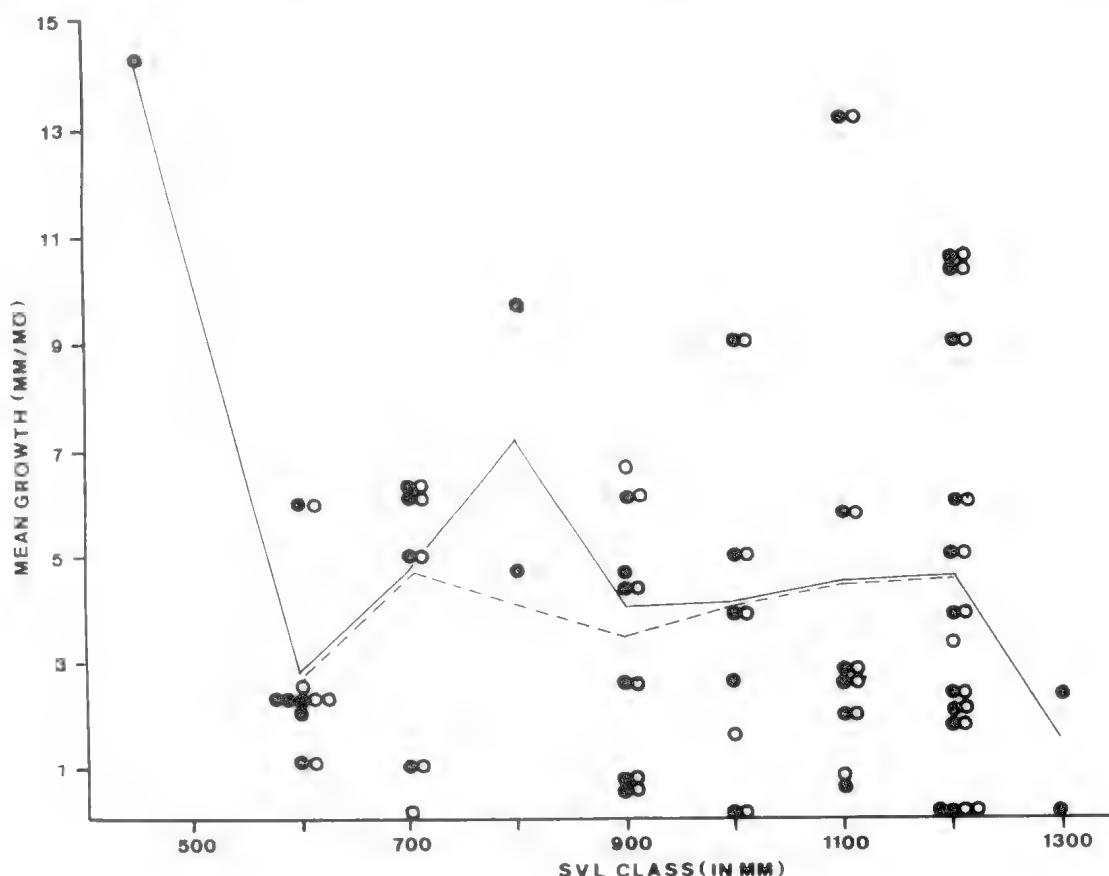

Fig. 2.   Mean monthly growth in length (SVL in mm) for marked-released-recaptured tiger snakes from West Franklin I. Dots represent males: open circles, females. Solid and dashed lines connect means for males and females, respectively, in each size class.

achieved in about 20 years (about 12 years in males) on the Franklin Islands.

Several extrinsic factors obviously affect growth in the natural environment (Andrews 1982). Primary among these are (1) the availability of food, (2) the effects of temperature, and (3) interspecific and intraspecific competition and/or predation.

Prey types vary markedly among tiger snake populations, particularly on islands. Diets are composed almost entirely of frogs in most mainland areas (Shine 1978), whilst island populations (except for Kangaroo I. and Tasmania) are devoid of frogs. Tiger snakes on many islands, eat small mammals, birds, and/or lizards (Schwaner, in press). Little is known of the effects of differing quantity and quality of prey among natural populations of tiger snakes (Shine 1978). However, a high correlation between maximal body size and mean weight of available prey exists for several offshore island populations of tiger snakes in South Australia (Schwaner, in press).

Seasonal variations in temperature apparently affect the feeding habits of tiger snakes on the Franklin Islands (Schwaner, in prep.) Adults (> 1000 mm SVL) do not feed during winter months apparently because they are unable to digest large prey and apparently do not eat small prey. Under laboratory conditions these snakes regurgitated large prey at body temperatures lower than those measured when the prey was ingested. Survival of island tiger snakes during winter may depend heavily on their ability to store body fat. On the Franklin Islands (and on Chappell Island) adult tiger snakes feed primarily on muttonbirds *(Puffinus tenuirostris)*, a highly seasonal prey (Worrell 1958; Schwaner, in press). Adult female snakes are gravid during this season, but Shine (1978) and Schwaner (in press) indicated that gravid tiger snakes do not feed. Alternatively, the size at which the laboratory reared snakes were observed to increase markedly in weight relative to length (Fig. 1) is approximately the size at transition from juveniles to adults in both the Chappell Island population and the tiger snakes on the Franklin Islands. Increased weight to length ratios suggesting fat deposition may therefore be related to the onset of reproductive maturity in these snakes.

Most islands supporting populations of tiger snakes lack natural predators. Kangaroo Island has goannas *(Varanus rosenbergi)* and the undescribed pygmy copperhead snake *(Austrelaps* sp.), both known predators of snakes. On Reevsby Island near Port Lincoln, goannas have been introduced and may have reduced directly numbers of tiger snakes (Mirtschin 1982). On St Peters Island off the western coast of Eyre Peninsula near Ceduna,

goannas may have reduced the numbers of tiger snakes indirectly by feeding on muttonbird eggs (T. Mertens, *in litt.*, 3.iii.84). Mainland populations of tiger snakes appear to reach smaller maximum body sizes than most island populations but no direct link with predators or competitors has yet been established as a correlated factor.

If there was an optimum natural environment for feeding and growth in black tiger snakes, growth rates in those environments would be expected to exceed those of the artificial laboratory environment. Recognition that actual growth rates in natural populations vary due to particular extrinsic factors (e.g. variable food availability) can be accomplished by comparative studies among different island populations both in the field (Schwaner, in press) and in the laboratory.

Whereas variable growth rates appear to be an adaptive strategy for ectothermic vertebrates (Pough 1980), and one which is highly affected by extrinsic factors, a most important question concerns intrinsic interpopulational (intraspecific) differences in growth rates. Andrews (1982) has suggested that one method of defining the relationship between growth and fitness can be explored using experimental manipulation of food availability in laboratory settings. Certain differences in growth rates may occur between sexes, as adaptations to particular life styles (or differential resource availabilities) and by wide variation among individuals reared under similar conditions (Andrews 1982). Among island populations tiger snakes differ in maximal body size by as much as an order of magnitude (Schwaner, in press). Also, within and among populations, sexual dimorphism in maximal body size is extreme for some populations, with males greater than females, whilst in other populations females equal males in body size, or are slightly larger. This study has demonstrated that tiger snakes fed *ad libitum* grow at predictable rates. Similar comparative studies of growth in captive snakes from other island populations with different maximal body sizes may reveal whether these rates are adaptive or are simply environmentally determined.

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A REDEFINITION OF UPEROLEIA RUGOSA (ANDERSSON) (ANURA: LEPTODACTYLIDAE)

BY MARGARET DAVIES & KEITH R. MCDONALD

Summary

Topotypic Uperoleia rugosa were examined and their morphology, osteology and advertisement calls described.

A REDEFINITION OF *UPEROLEIA RUGOSA* (ANDERSSON) (ANURA: LEPTODACTYLIDAE)

by Margaret Davies* & Keith R. McDonald†

Summary

Davies, M. & McDonald, K. R. (1985) A redefinition of *Uperoleia rugosa* (Andersson) (Anura: Leptodactylidae) *Trans. R. Soc. S. Aust.* 109(2), 37–42, 28 June, 1985.

Topotypic *Uperoleia rugosa* were examined and their morphology, osteology and advertisement calls described.

KEY WORDS: Morphology, osteology, advertisement calls, *Uperoleia rugosa*.

Introduction

Frogs of the leptodactylid genus *Uperoleia* Gray are small, short limbed, fossorial animals exhibiting limited morphological diversity. A recent revision and subsequent papers by Tyler, Davies & Martin (1981a,b,c) resulted in the recognition of 18 species. The revision was concerned principally with those species occurring in that part of the continent investigated by the authors (the Kimberley Division of Western Australia, and the Northern Territory); attention to taxa occurring in the eastern states was confined to an examination of type material of species described from that area.

Because of the limited interspecific morphological divergence in *Uperoleia*, species concepts rely heavily upon biological data, particularly cell information.

Uperoleia rugosa (Andersson) is one of the eastern species recognised by Tyler *et al.* (1981a). Since its description in 1916 it has been reported widely from Queensland, New South Wales and Victoria (Barker & Grigg, 1977, Cogger *et al.*, 1983). The type locality of *U. rugosa* is reported to be Colosseum Qld by Andersson (1916). However, a label accompanying the type specimen states it was collected at Mt Colosseum. Colosseum is situated on the plains at the foot of Mt Colosseum and in 1912 was served by a now abandoned railway siding.

During a visit to the area in December 1984, one of us (K.R.McD.) obtained a series of specimens and recorded the advertisement call. The availability of this topotypic material permits a study of skeletal structure. Here we describe the material.

Materials and Methods

Specimens examined here are deposited in the Naturhistoriska Riksmuseet, Stockholm (NRAM)

and the South Australian Museum, Adelaide (SAM).

Methods of measurement follow Tyler *et al.* (1981a). Measurements taken were: eye diameter (E) eye to naris distance (E-N), internarial span (IN), snout to vent length (S-V) and tibia length (TL).

Osteological data were obtained from cleared and Alizarin Red-S stained specimens after the method of Davis & Gore (1947). Osteological descriptions follow Trueb (1979).

Calls were recorded with a Uher 4000 Report Monitor tape recorder and an AKG D190 ES microphone. Wet bulb air temperatures were measured with a Schultheiss rapid-reading thermometer within 3 cm of the calling site.

Calls were analysed by means of a sound spectrograph (Kay Model 6061-B Sona-Graph) with the overall response curve maintained in the FL-1 position. Temporal and spectral characteristics of calls were determined from wide-band (300 Hz bandpass) spectrograms. Because of consistency between calls both within and between individuals, only single representative calls of each male were analysed and mean values calculated

Uperoleia rugosa (Andersson)
FIGS 1–6

Pseudophryne rugosa Andersson, 1916, K. Sven. Vetenskapsakad. Handl. 52, 9, p. 13.

Uperoleia rugosa: Parker, 1940, Novitates Zool. 42, p. 70 (part.); Tyler, Davies & Martin 1981, Aust. J. Zool. Suppl. Ser. 79, p. 17; Cogger 1983, Reptiles and Amphibians of Australia, 3rd edn, p. 86; Cogger, Cameron & Cogger 1983, Zoological Catalogue of Australia Vol. 1 Amphibia and Reptilia, p. 34 (part.).

Material examined

NRAM 1630, holotype, gravid ♀, Mt Colosseum (24°24′, 151°37′) S.E. Qld, xi.1912, E. Mjöberg; SAM R27052-3, R27054-5 (cleared and stained), calling ♂♂, nr site of former Colosseum railway station (24°21′, 151°37′), 12.xii.1984, K. R. McDonald.

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† Queensland National Parks & Wildlife Service, Pallarenda, Townsville, Qld 4810
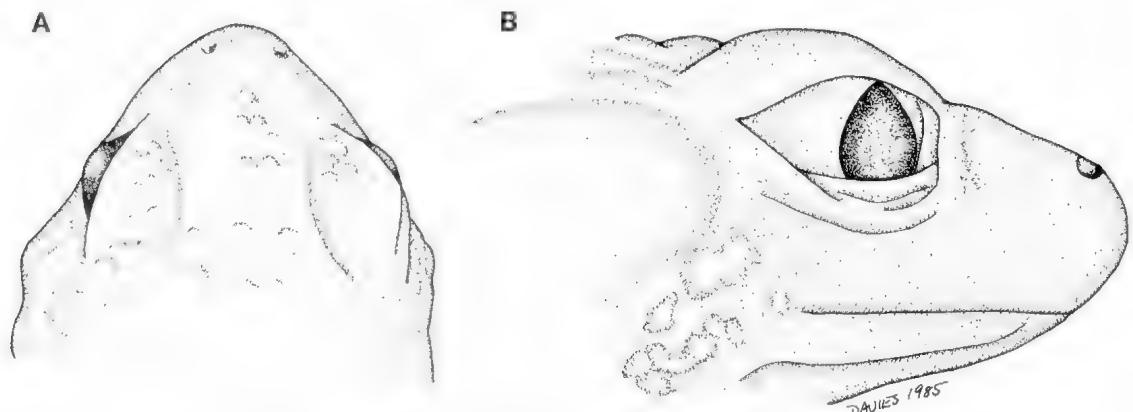
Fig. 1. A lateral and B dorsal views of the head of male *Uperoleia rugosa* (SAM R27052).

Definition

A small species (♂♂ 19-22 mm, ♀ 21 mm) characterised by moderate hind limbs (TL/S-V 0.35-0.39); fringed toes with a trace of basal webbing; maxillary teeth absent; prominent subarticular and palmar tubercles; unexposed frontoparietal fontanelle; mating call a short note of four pulses.

Redescription of species (based on SAM R27052)

Maxillary teeth absent. Vomerine teeth absent. Snout short, slightly truncated when viewed from above (Fig. 1A) and in profile. Eye to naris distance greater than internarial span (E-N/IN 1.43). Canthus rostralis inconspicuous and straight. Tympanum not visible externally (Fig. 1B).

Fingers moderately long, slender, unwebbed but slightly fringed with prominent palmar and subarticular tubercles (Fig. 2A). Prominent supernumerary subarticular tubercles present. Fingers in order of length 3 > 4 > 2 > 1. Hind limbs moderately long (TL/S-V 0.36). Toes moderately long, fringed with a trace of basal webbing (Fig. 2B). In order of length 4 > 3 > 5 > 2 > 1. Metatarsal tubercles moderately large but prominent. Subarticular tubercles rounded. Dorsal surface faintly tubercular. Parotoid and inguinal glands well developed; coccygeal glands poorly developed. Submandibular gland prominent, discrete (Fig. 1A). Cloacal flap with tiny fimbriations. Ventrally, throat and thorax granular, belly smooth. Male with unilobular, submandibular vocal sac and glandular nuptial pad.

In preservative, dorsum brown with darker brown markings between eyes, in scapular region and on posterior portion of dorsum. Dorsal tubercles tipped with cream. Parotoid and inguinal glands with few cream patches. Inguinal and post femoral patches pink after one month in preservative. Nuptial pad white.

Ventral surface cream with few small, isolated areas of brown pigment. Submandibular region and thorax, except for small medial patch, dark grey.

Colour in life

Dorsum grey/brown with darker brown markings. Dorsal tubercles tipped with yellow; parotoid and inguinal glands yellowish; submandibular gland yellow. Bright reddish orange inguinal and femoral patches.

Ventral surface white with brown areas of pigment. Submandibular region dark grey to black sometimes extending to pectoral region.

Dimensions (in mm)

Snout-vent length 20.9; tibia length 7.6; eye diameter 2.6; eye-naris distance 2.0; internarial span 1.4.

Variation

The addition material ranges 19.75-21.7 mm S-V. Relative lengths of tibia are consistent (TL/S-V 0.36-0.39). E-N/IN ranges 1.24-1.67. The specimens vary little morphologically from the described specimen.

The snout is more rounded in two of the specimens, and the belly is faintly granular in others. Cream patches on the dorsal glands are slightly more prominent in a few specimens and the pigment patches on the ventral surface are less discrete in one specimen.

The material varies little from the holotype, although dorsal colouration and patterning can be observed. This feature conforms with Andersson's description (see Tyler *et al.*, 1981a). The pigmentation of the ventral surface was not reported

A

B
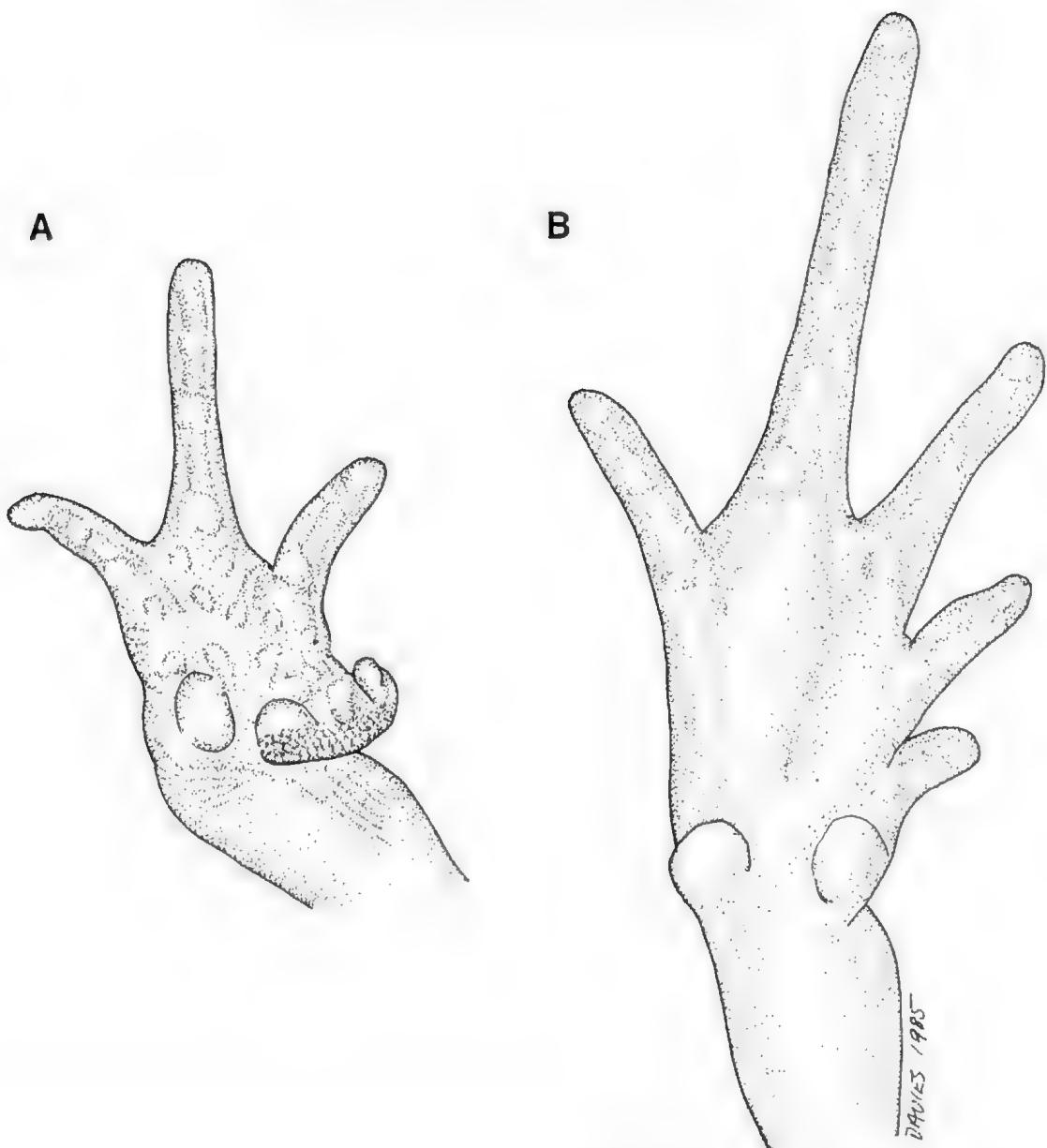
Fig. 2. A palmar and B plantar views of the hand and foot of male *Uperoleia rugosa* (SAM R27052).

by Andersson (1916), and is not apparent in the holotype.

Osteology (based on SAM R27055)

Skull well ossified, sloping anteroventrally. Sphenethmoid not ossified dorsomedially or ventromedially; small portion ossified posteriorly to medial extremities of palatines, with ossified portion extending about 1/3 length of orbit in ventral view. Prootic not fused with exoccipital. Exoccipital confluent posteromedially in dorsal view but not fused ventromedially. Crista parotica short, stocky, not articulating with otic ramus of squamosal lying alongside lateral extremities. Grooves of carotid canal present on frontoparietals, medial to epiotic eminences.

Frontoparietal elements extensive, crenate medially, overlying sphenethmoid anteriorly, more widely separated anteromedially. Frontoparietal fontanelle barely exposed medially; anterior margin formed by sphenethmoid elements at level about 1/5 posteriorly on length of orbit. Posterior margin
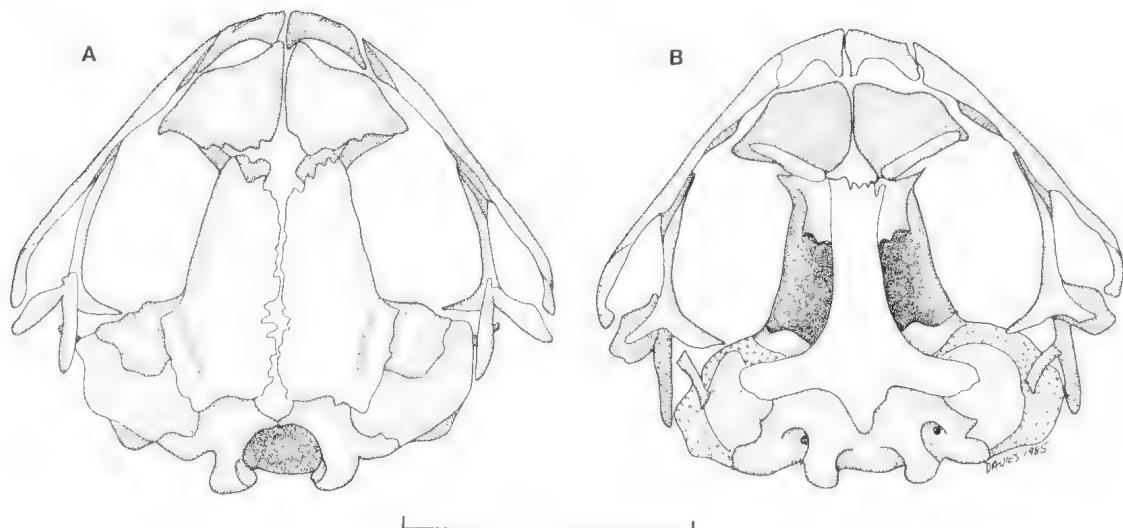
Fig. 3. A dorsal and B ventral views of the skull of male *Uperoleia rugosa* (SAM R27055).

undefined because of lack of anteromedial ossification of exoccipital.

Nasals large, closely applied medially for 4/5 length, slightly separated posteromedially (Fig. 3A). Anteromedial extremities crescentic. Maxillary processes moderately acute, directed ventrally, not in bony contact with pars facialis of maxillary. Posteromedially nasals in contact with anterior extremities of sphenethmoid. Palatines moderately slender, angled at about 45° to sphenethmoid, reduced laterally, not reaching extremities of maxillary processes of nasals.

Parasphenoid robust. Cultriform process broad, irregularly truncate (Fig. 3B), expanded slightly posterolaterally. Alary processes moderately long, moderately broad, angled slightly postero-laterally, reaching medial extremities of medial ramus of pterygoid. Medial ramus of pterygoid broad, anterior ramus in long contact with well developed pterygoid process of palatal shelf of maxillary. Cartilaginous quadrate present between base of squamosal and quadratojugal. Quadratojugal robust, in firm contact with maxillary. Squamosal stocky with tiny zygomatic ramus and long, unexpanded otic ramus.

Maxillary and premaxillary edentate; palatal shelf moderately deep with well developed palatine processes, not abutting medially. Pterygoid process well developed. Alary processes of premaxillary perpendicular to pars dentalis, slender, inclined medially. Pars facialis of maxillary moderately deep; preorbital process absent. Vomers absent. Bony columella present.

Pectoral girdle arciferal and robust. Omosternum absent, xiphisternum present. Sternum
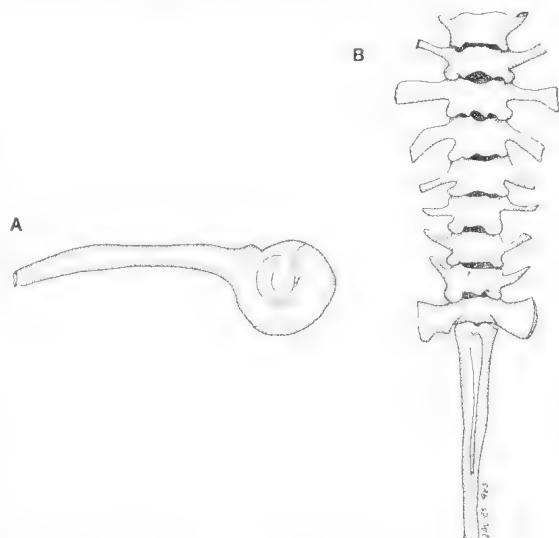
Fig. 4. A lateral view of pelvic girdle and B dorsal view of vertebral column of *Uperoleia rugosa* SAM R27055.

cartilaginous. Clavicles slender, curved, closely applied medially. Coracoids well developed, robust, widely separated medially. Scapula bicapitate, slightly shorter than clavicles. Suprascapular about 2/3 ossified.

Eight non-imbricate presacral vertebrae (Fig. 4B). Sacral diapophyses poorly expanded. Relative widths of transverse processes III > IV > sacrum > II > V– VI > VII = VIII. Bicondylar sacrococcygeal articulation. Crest on urostyle extending approximately 1/2 length. Ilium with tiny dorsal prominence and moderately large lateral protuberance (Fig. 4A).

Humerus with strongly developed anteroproximal crest. Phalangeal formula of hand 2,2,3,3; small bony prepollex, palmar sesamoid. Phalangeal formula of foot 2,2,3,4,3. Well developed bony prehallux.

Variation

A second topotypic specimen was examined (SAM R27056). The specimen varied in the nature of the extremities of the frontoparietal elements; anterior extremities were truncate and medial edges were straight, not crenate. The nasals were in tenuous contact with the frontoparietals. The exoccipitals were not confluent posteromedially. In other features, the skeleton approximated the above description closely.

Advertisement call

The advertisement calls of three individuals were recorded at Colosseum on 12.xii.1984. The call is
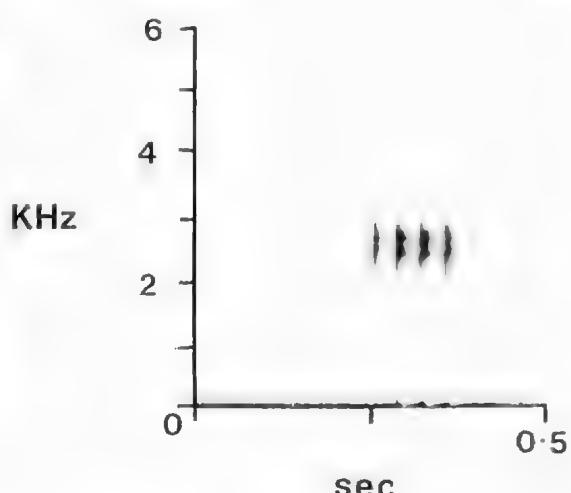
Fig. 5. Sonagram of male advertisement call of *Uperoleia rugosa* SAM (R27053). Temperature – 22.8°C.

TABLE 1. *Advertisement call characteristics of* Uperoleia rugosa *at Colosseum, Queensland.*

| Specimen	No. of pulses	Duration (ms)	Pulse repetition rate (pulses sec⁻¹)	Dominant frequency (Hz)	Wet-bulb temp. °C
SAM R27052	4	120	33.33	2500	22.6
SAM R27053	4	120	33.33	2500	22.8
SAM R27055	4	110	36.55	2750	22.2
Mean	4	116.7	34.40	2583	22.5

a short note of four pulses, pulsed at about 34 pulses sec⁻¹ and with a duration of about 117 msec. The dominant frequency is about 2,583 Hz. A sonogram of the advertisement call is shown in Fig. 5, and characteristics of the calls are listed in Table 1.

Habitat

Frogs were located on the lower slopes and adjacent plains of Mt Colosseum. The lower slopes are disturbed forest of *E. tessellaris* F. Muell., *E. tereticornis* Smith, *E. crebra*, and *Melaleuca quinquenervia* (Cav.) S. T. Blake. Most of the plain is heavily disturbed and is mainly grassland with scattered large tress of *E. tereticornis* (Fig. 6).

The frogs were found around temporary summer-filled pools and were calling in short grass on banks 1–6 m from water. Calling was heard only following a thunderstorm of approx. 25 mm rain.

Other frogs heard and seen in the area were: *Litoria caerulea, L. fallax, L. rubella, L. rothii, L. inermis, L. nasuta, L. alboguttata, Ranidella* cf. *deserticola, Adelotus brevis, Limnodynastes peroni,*

L. terraereginae, L. ornatus, L. tasmaniensis and *Bufo marinus.*

Andersson (1916) described the habitat at Colosseum as open forest-country.

Fig. 6. Habitat in which calling males of *Uperoleia rugosa* were found near former railway station, Colosseum, Qld.

Discussion

In revising *Uperoleia*, Tyler *et al.* (1981a) redefined the three named eastern Australian species, *U. rugosa* (Andersson), *U. fimbrianus* (Parker) and *U. laevigata* Keferstein, all from the type specimens. They resurrected *U. fimbrianus* from the synonymy of *U. rugosa* in view of their experience with restricted distributions amongst taxa elsewhere in Australia, and because of its larger size.

They also indicated the existence of a number of undescribed species in eastern Australia that await resolution. Cogger (1983) considered the eastern Australian species to be composite.

Since the revision of Tyler *et al.* (1981a), *U. lithomoda*, Tyler, Davies & Martin, has been shown by Tyler & Davies (1984) to have a wide-ranging distribution across the continent. Evidently not all species of *Uperoleia* have restricted distributions, and hence the status of *U. fimbrianus* rests solely on its large size.

The data presented here clarify the status of *U. rugosa*: a step vital to resolution of the status of *U. fimbrianus* and of the identity of other eastern Australian taxa. Cogger *et al.* (1983) gave the distribution of *U. rugosa* as N.E. coastal, S.E. coastal, Murray-Darling basin, Bulloo River basin, Qld and N.S.W. (A.C.T.). The A.C.T. records probably are based upon the work of Robertson (1982¹, 1984a,b). However, the species studied by him is "*U. rugosa* [type B]" *sensu* Littlejohn (1967), a toothed species not conspecific with the untoothed *U. rugosa* and currently under investigation by Davies & Littlejohn (in prep.).

Here we have demonstrated only the identity of *U. rugosa* from S.E. coastal Queensland. The extent of the geographic range of the species awaits clarification of the status of *U. fimbrianus* (Davies & Littlejohn, in prep.).

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A NEW SPECIES OF PHASCOLOSOMA (SIPUNCULA) FROM AUSTRALIA

BY S. J. *EDMONDS*

Summary

A new species of sipunculan, Phascolosoma kapulam sp. nov. dredged from off the coast of New South Wales, is described. It is distinguished from other species of Phascolosoma by the shape of its introvert hook.

A NEW SPECIES OF *PHASCOLOSOMA* (SIPUNCULA) FROM AUSTRALIA

by S. J. EDMONDS*

Summary

EDMONDS, S. J. (1985) A new species of *Phascolosoma* (Sipuncula) from South Australia. *Trans. R. Soc. S. Aust.* **109**(2), 43-44, 28 June, 1985

A new species of sipunculan, *Phascolosoma kapalum* sp. nov. dredged from off the coast of New South Wales, is described. It is distinguished from other species of *Phascolosoma* by the shape of its introvert hook.

KEY WORDS: Sipuncula, *Phascolosoma kapalum* sp. nov., shape of introvert hooks.

Phascolosoma (phascolosoma) kapalum sp. nov.
FIGS 1-2

Phascolosoma Leuckart, 1828; Fisher, 1952: 422; Stephen & Edmonds, 1972: 270.
Type locality: Stn K77-23-06, 33°40′S, 151°56′E, off coast of New South Wales; dredged at 710 m, during cruise of "Kapala", coll. P. Colman & D. Brown, 6.xii.1977.
Type specimen: Australian Museum Sydney: W 17004
Paratype: South Australian Museum: E 1694
Description:
Trunk: Length 13-32 mm, maximum width near mid-region 4-7 mm. Subcylindrical to spindle-like and sometimes covered or partly so with coating of very fine particles of adherent mud. Thin walled. Longitudinal musculature grouped into 24-32 anastomosing bundles, usually visible externally.

Introvert: Slender and almost completely retracted in all specimens. Length ½-¾ trunk. Finger-like tentacles present which do not appear to surround mouth of dissected specimen. Numerous rows of single-pointed introvert hooks, 0.075-0.095 mm wide basally and with vertical height 0.070-0.090 mm. Hook with a lateral extension of its basal portion on side away from tip of hook. Hook uniformly brown except for clear streak (running from tip to mid-basal region), very narrow anteriorly but wider basally. Twelve or more basal bodies at base of hook on same side as tip.

Papillae: Most prominent at anterior and posterior regions of trunk and at base of introvert. Mostly hemispherical but may be bulbous, subclavate or conical. Central pore usually surrounded by 5-7 pigmented plates and sometimes elevated so that papillae appear mamillate. Largest hemispherical forms about 0.3 mm in diameter, subclavate forms 0.3-0.4 mm in height.
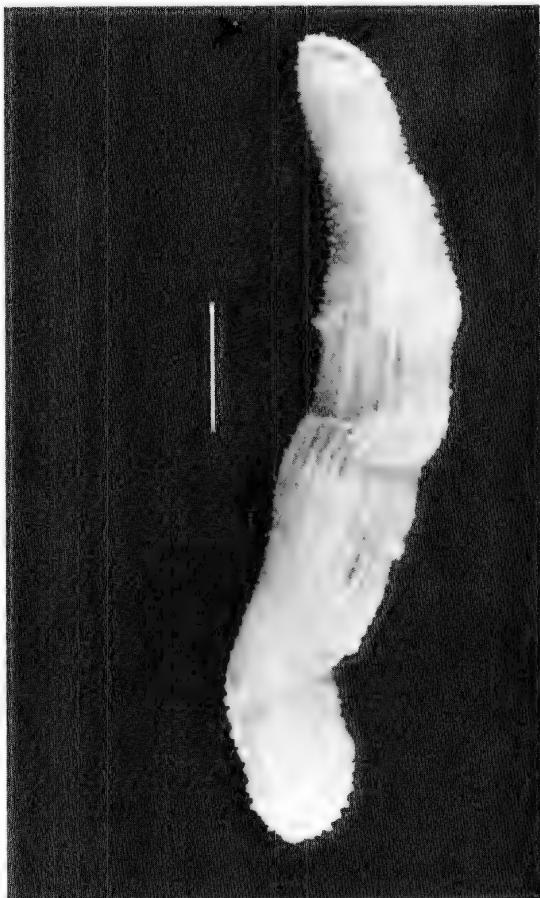
Fig. 1. *Phascolosoma kapalum* sp. nov., entire specimen (scale bar = 5 mm).

Refractor muscles: Four, consisting of a strong ventral pair arising from muscles 3-6, 4-7 or 5-8 in posterior third of trunk and a weaker dorsal pair more anteriorly from muscles 6-7, 6-9 or 7-9. Dorsal and ventral muscle on each side fused anteriorly.

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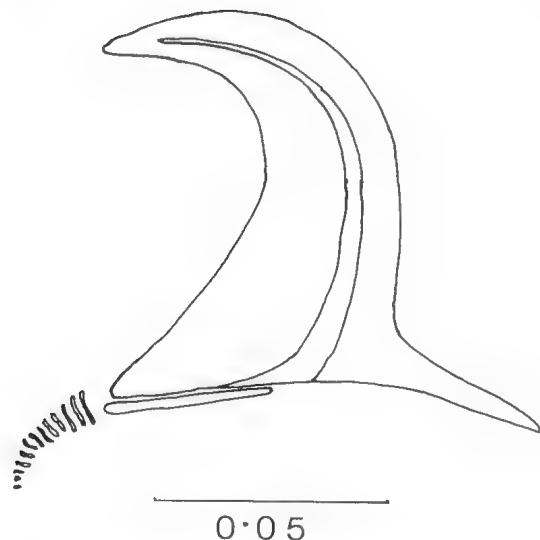
Fig. 2. *Phascolosoma kapalum* sp. nov., introvert hook
(scale bar in mm).

Nephridia: Two; long, tubular and thin walled, extending to mid-region or posterior half of trunk fixed to body wall for about ¾ length and opening to exterior at about same level as anus or just anterior to it.

Alimentary canal: Short oesophagus and long coiled intestine. One fastening muscle to anterior intestine. Spindle muscle, arising anteriorly from below anus, is fixed posteriorly. Intestinal caecum and wing muscle. Contractile vessel without villi.

Brain with 2 eye spots.

Systematic position

This species of *Phascolosoma* falls in the subgenus *Phascolosoma* s.s. (Stephen & Edmonds 1972). It is distinguished from all other members of the sub-genus by the structure of its introvert hook, especially its basilateral extension. The species is not included in Edmonds (1980).

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SURFACE ARCHITECTURE OF THE DORSAL EPIDERMIS IN AUSTRALIAN FROGS

BY MICHAEL J. TYLER & CHRISTOPHER A. MILLER

Summary

Two distinct forms of surface architecture of the epidermal squamos epithelium occur in Australian frogs of the families Hylidae and Leptodactylidae: one consisting of an elaborate pattern of microplicae; the other a reticulum. Each species exhibits only one form but species that are closely related phylogenetically and ecologically may differ in the nature of the epithelial architecture.

SURFACE ARCHITECTURE OF THE DORSAL EPIDERMIS IN AUSTRALIAN FROGS

by Michael J. Tyler & Christopher A. Miller*

Summary

Tyler, M. J. & Miller, C. A. (1985) Surface architecture of the dorsal epidermis in Australian frogs. *Trans. R. Soc. S. Aust.* 109(2), 45-48, 28 June, 1985.

Two distinct forms of surface architecture of the epidermal squamous epithelium occur in Australian frogs of the families Hylidae and Leptodactylidae: one consisting of an elaborate pattern of microplicae; the other a reticulum. Each species exhibits only one form but species that are closely related phylogenetically and ecologically may differ in the nature of the epithelial surface architecture.

KEY WORDS: Frogs, SEM, epidermis, ultrastructure.

Introduction

The dorsal skin of frogs is an extremely complex tissue, containing mucous and granular glands whose contents are discharged to the external surface via ducts (Elkan, 1968). The mucous glands are under the control of sympathetic nerves; the mucus liberated assists temperature control via evaporative cooling, and, by maintaining a moist surface, also enables the dorsal skin to function as a respiratory surface (Lillywhite, 1971). In contrast the secretions of the granular glands of many species are toxic, and afford these animals protection against some predators (Daly & Myers, 1967).

The ventral skin is aglandular in the vast majority of species and either smooth or distinctly granular. Functionally it is involved in water uptake, and species liable to extreme water loss adopt a stance in which granular skin is adpressed to the substrate during periods of active restoration of body water (Stille, 1958; Johnson, 1969).

The histology of frog skin has been reviewed by Elias & Shapiro (1957) and Elkan (1968). These studies have documented gross structure and described the glands dispersed throughout the skin. In addition, the secretions of aggregations of glands to form parotoid glands (as in *Bufo* species) or calf glands (in the Australian leptodactylid species *Limnodynastes dumerili*) have been the subject of specific studies (Low, 1972; Crook & Tyler, 1981).

As is typical for vertebrate animals, the outer epidermis is composed of squamous epithelial cells arranged as a stratum corneum. Electron microscopic studies of the outer surface of squamous epithelia in various vertebrates has revealed an elaborate pattern of elevated or depressed whorls and ridges (Hawkes, 1974; Fahrenbach & Knutson, 1975; Andrews, 1976; Kaltenbach, Harding & Susan, 1980).

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Here we have examined the ultrastructure of dorsal epidermal cells in Australian frogs, to establish the nature of the diversity in surface architecture and its possible relationship to the systematic arrangement of those species. It includes more genera and species than any previous survey of skin architecture of the Anura, and is the first investigation of Australian species.

Materials and Methods

Adult representatives of the following 17 genera and 50 species were examined: *Adelotus brevis, Assa darlingtoni, Crinia georgiana, Cyclorana australis, C. cultripes, C. longipes, C. maculosus, C. maini, C. platycephalus, Heleioporus eyrei, Lechriodus fletcheri, Limnodynastes convexiusculus, L. dumerili, L. ornatus, L. spenceri, L. tasmaniensis, Litoria adelaidensis, L. alboguttata, L. bicolor, L. caerulea, L. chloris, L. coplandi, L. dahlii, L. dentata, L. ewingi, L. fallax, L. freycineti, L. gracilenta, L. inermis, L. pallida, L. peroni, L. raniformis, L. rothii, L. rubella, L. tinmeri, Megistolotis lignarius, Mixophyes fasciolatus, Neobatrachus pictus, N. sutor, Notaden bennetti, N. melanoscaphus, Pseudophryne bibroni, P. guentheri, Ranidella riparia, R. signifera, Rheobatrachus silus, Taudactylus acutirostris, T. diurnus, Uperoleia inundata* and *U. trachyderma.* The selection of species reflects an attempt to sample diverse genera, but was subject to the availability of material.

Portions (5 × 5 mm) of dorsal skin were removed from frogs that had been killed by contact with a 3% solution of chloral hydrate, fixed in 3% formalin whilst still in a relaxed state and stored in 65% alcohol. The tissues were critical-point dried using the liquid CO_2/amyl procedure in a Polaron E 3000 C.P. drier, or else simply air-dried in a desiccator. Specimens were coated with 15 nm carbon and 20 nm gold/palladium (80:20), and viewed in an ETEC scanning electron microscope at 20 Kv.
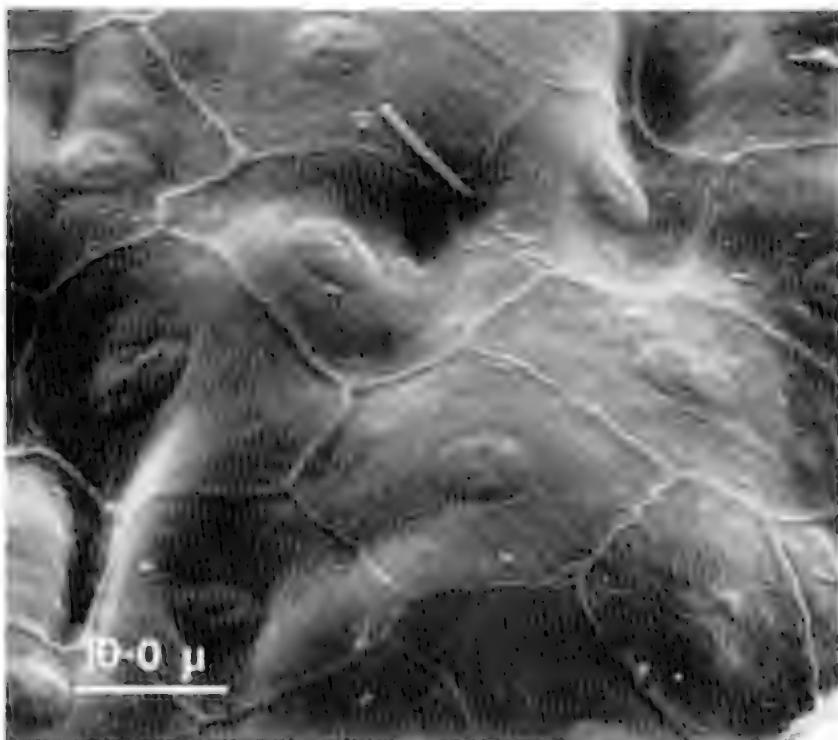
Fig. 1. SEM view of squamous epithelial cells of skin of *Cyclorana maini* showing hexagonal shape.
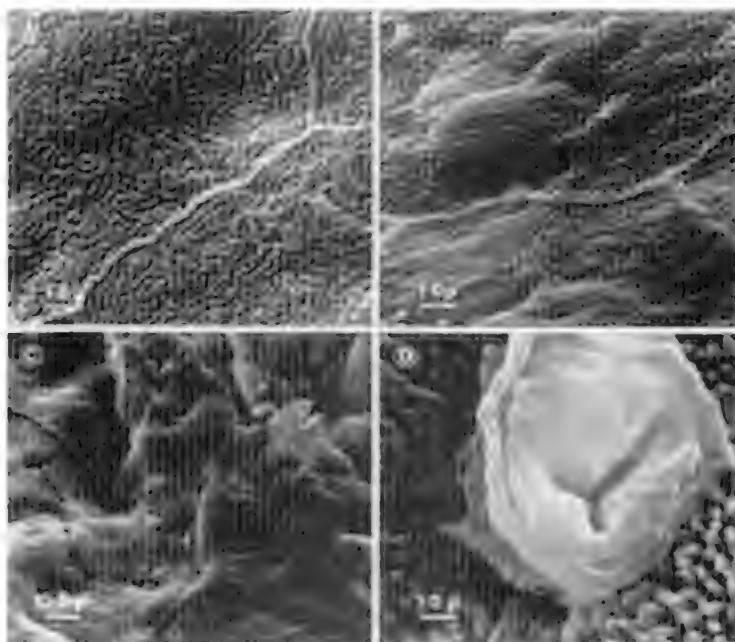

Fig. 2. SEM view of dorsal skin of: A. *Litoria freycineti* showing microridges on the cell surface. B. *Crinia georgiana* showing a reticular cell surface. C and D. Sloughing of skin of *Uperoleia trachyderma*. In D the central portion is the aperture to a dermal gland duct surrounded by intercellular connections.

Results

In the species examined, the surface cells of the stratified squamous epithelium are polygonal (usually hexagonal) (Fig. 1). Upon these cells two forms of surface architecture occur. One is a complex pattern of curved elevated ridges corresponding to the "microridges" of Hawkes (1974) and the "microplicae" of Andrews (1976) (Fig. 2A). The second form is in the arrangement of an extremely dense reticulum (Fig. 2B). It appears similar to the type of surface that Kaltenbach *et al.* (1980, p. 323) described as having "a spongy appearance".

The incidence of these two forms of surface architecture of the squamous epithelium in the species and genera examined is summarised in Table 1.

To establish the existence of intraspecific variation, dorsal skin from six *Litoria ewingi* and six *Ranidella riparia* was examined. Within each species there was no detectable variation in surface architecture. We did not observe any difference in the quality of preparations associated with the drying techniques. We examined a variety of preparations in which the outer epidermal cells could be seen to be lifting away from the underlying cells and which we attributed to represent normal ecdysis. Examples are shown in Figs 2C and 2D. The projections from the surface of the cells in Fig. 2D are considered to represent intercellular

TABLE 1. *Incidence of two forms of dorsal, dermal architecture amongst 17 genera and 50 species of Australian frogs.*

Genus	Family	No. of spp. examined	Surface architecture	
			Microridges	Reticulum
Adelotus	L	1	0	brevis
Assa	L	1	0	darlingtoni
Crinia	L	1	0	georgiana
Cyclorana	H	6	australis cultripes maculosus maini	longipes platycephalus
Heleioporus	L	1	0	eyrei
Lechriodus	L	1	0	fletcheri
Limnodynastes	L	5	0	convexiusculus dumerili spenceri tasmaniensis ornatus
Litoria	H	19	adelaidensis bicolor caerulea coplandi dentata ewingi fallax freycineti gracilenta inermis peroni raniformis rothii rubella	alboguttata chloris dahlii pallida tornieri
Megistolotis	L	1	0	lignarius
Mixophyes	L	1	0	fasciolatus schevilli
Neobatrachus	L	2	pictus sudori	0
Notaden	L	2	0	bennetti melanoscaphus
Pseudophryne	L	2	0	bibroni guentheri
Ranidella	L	2	0	riparia signifera
Rheobatrachus	L	1	silus	0
Taudactylus	L	2	0	acutirostris diurnus
Uperoleia	L	2	0	inundata trachyderma

H = Hylidae; L = Leptodactylidae

connections. None of the preparations examined demonstrated any evident intermediate stages, documenting the change between the presence of the intercellular connections and the formation of the final surface architecture.

Discussion

The results demonstrate that two forms of surface architecture of the squamous epithelium of the dorsal epidermis occur in the species of Australian hylid and leptodactylid frogs examined.

The results also indicate that there is no significant variation within species, and that the changes associated with ecdysis reveal at the surface intercellular connections comparable to those reported by Kaltenbach *et al.* (1980). We have not observed amongst the preparations examined any surface architecture not resembling the two types reported above. We have no evidence to suggest that either form of cell surface is an intermediate stage in the cytogenesis or cytomorphosis of the other, but we cannot exclude the possibility of an age-related change taking place so rapidly that it was not represented in our large sample.

Of the nine polytypic genera, two (*Cyclorana* and *Litoria*) include some species with cellular microridges and others with cell surfaces in the form of a reticulum. Nevertheless in the majority of species in each genus the surface bears microridges. This division separates species that are considered phylogenetically closely related: the reticular surfaced *L. alboguttata* and *L. dahlii* were placed by Tyler & Davies (1978) in a species-group with the microridge surfaced *L. raniformis*. Similarly the reticular surfaced *L. pallida* and *L. tornieri* have

been shown by Davies, Martin & Watson (1983) to be very closely related to the microridged *L. inermis*. Of the two reticular surfaced *Cyclorana* species, *C. platycephalus* is certainly phylogenetically remote from all congeners, but *C. longipes* is very closely related to the microridge surfaced *C. maculosus*.

Because of the difference in these last two species which also occupy identical habitats and have similar life histories and habits, it is apparent that the difference is not associated with any major ecological shift, nor is of any systematic significance. The fundamental similarity amongst diverse vertebrate classes precludes any obvious common function beyond that of increasing the surface area. Particularly elaborate architecture has been observed on the surface of the oesophagus of the rhesus monkey and rat cornea (Andrews, 1976). That author noted that the microplical and interplical grooves would serve to hold mucus. Whereas this structure may have a protective lubricating function in areas such as the oesophagus where the cells are alive, on the outer surface of frog skin it is more likely to improve the efficiency of gas exchange, simply by increasing the available surface area.

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A NEW CRETACEOUS CHIMAERID (PISCES: HOLOCEPHALI) FROM SOUTH AUSTRALIA

BY *J. A. LONG*

Summary

Edaphon eyrensis sp. nov. is described from a single left mandibular toothplate from the Aptian Bulldog Shale, west of Bopeechee Siding, northern South Australia. E. eyrensis is characterised by an angular oral margin and by the shape and arrangement of the fourth tritors. Comparisons are made with other Cretaceous and Tertiary chimaerid dentitions.

A NEW CRETACEOUS CHIMAERID (PISCES: HOLOCEPHALI) FROM SOUTH AUSTRALIA

by J. A. LONG*

Summary

LONG, J. A., (1985) A new Cretaceous chimaerid (Pisces: Holocephali) from South Australia. *Trans. R. Soc. S. Aust.* 109(2), 49-53, 28 June, 1985.

Edaphodon eyrensis sp. nov. is described from a single left mandibular toothplate from the Aptian Bulldog Shale, west of Bopeechee Siding, northern South Australia. *E. eyrensis* is characterised by an angular oral margin and by the shape and arrangement of the four tritors. Comparisons are made with other Cretaceous and Tertiary chimaerid dentitions.

KEY WORDS Pisces, Holocephali, Cretaceous, South Australia, new species, *Edaphon eyrensis*, mandibular.

Introduction

The chimaerids reached a peak of diversity during the Mesozoic, and though numerous genera are known from the Jurassic and Cretaceous of North America, U.S.S.R. and Europe (Newton, 1876; Woodward, 1892, 1912; Hussakoff, 1912; Obruchev, 1964) the only ones described from Australia are *Edaphodon sweeti*, *E. mirabilis* and *Ischyodus mortoni* from the Tertiary (Chapman & Pritchard, 1907; Chapman & Cudmore, 1924). The genus *Edaphodon* ranges from Early Cretaceous to Pliocene, with most species being Late Cretaceous in age. The specimen described here was found on the floor of Lake Phibbs, just south of Lake Eyre, and undoubtedly came from outcrops of the nearby Aptian Bulldog Shale (Ludbrook, 1966). It is therefore not only the first record of a fossil chimaerid from the Mesozoic of Australia (and the only chimaerid fossil from South Australia) but also one of the earliest species of *Edaphodon*. Cretaceous chimaerid toothplates are also known from New Zealand but these belong to *Callorhynchus hectori* and *Ischyodus brevirostris* (Newton, 1876).

Systematic Palaeontology

CLASS HOLOCEPHALI

ORDER CHIMAERIDA

SUBORDER CHIMAEROIDEI

FAMILY CHIMAERIDAE

GENUS *EDAPHODON* Buckland, 1838

Type species. Chimaera mantelli Buckland 1835, Cretaceous of England (Ward, 1973).

Remarks. The specimen is referred to *Edaphodon* because of its broad symphysial facet which

expands in breadth posteriorly, the number and arrangement of its tritors and the absence of a thickening on its outer face (Hussakoff, 1912, p. 202).

Edaphodon eyrensis sp. nov.
FIGS 1, 2, 3f.

1982 A large   toothplate of *Edaphodon* Long, p. 71
1984 *Edaphodon* sp. Long & Turner, p. 240.

Etymology. After Lake Eyre, near where the specimen was found.

Diagnosis. An *Edaphodon* having a mandibular toothplate twice as long as broad with four tritors: of which the two posterior and the single symphysial ones are large, and the lateral median one is small. Oral margin angular with anterior ends of outer and lateral median tritors forming right angles.

Material. Only one specimen, the holotype SAM P24770, maximum length = 110 mm.

Occurrence. From the floor of the Lake Phibbs approximately 21 km west of southwest from Bopeechee Siding, west of Marree, South Australia. Lower Cretaceous Bulldog Shale (Aptian).

Description. The bone is weathered, with the semidentine of the tritors being chalky. Despite this the overall shape of the toothplate and outline of the tritors are well preserved.

The oral margin of the mandibular toothplate (Figs. 1, 2, 3f) is quite angular as each of the two lateral tritors (outer tritor, OT; lateral median tritor, LMT) form right angles with the bone in between them. Overall the toothplate is rhomboidal with its breadth exactly half the length. The two large tritors in the posterior half (outer tritor, OT; mesial tritor, MT) are each about a quarter as broad as long and in contact for close to half their lengths. The median

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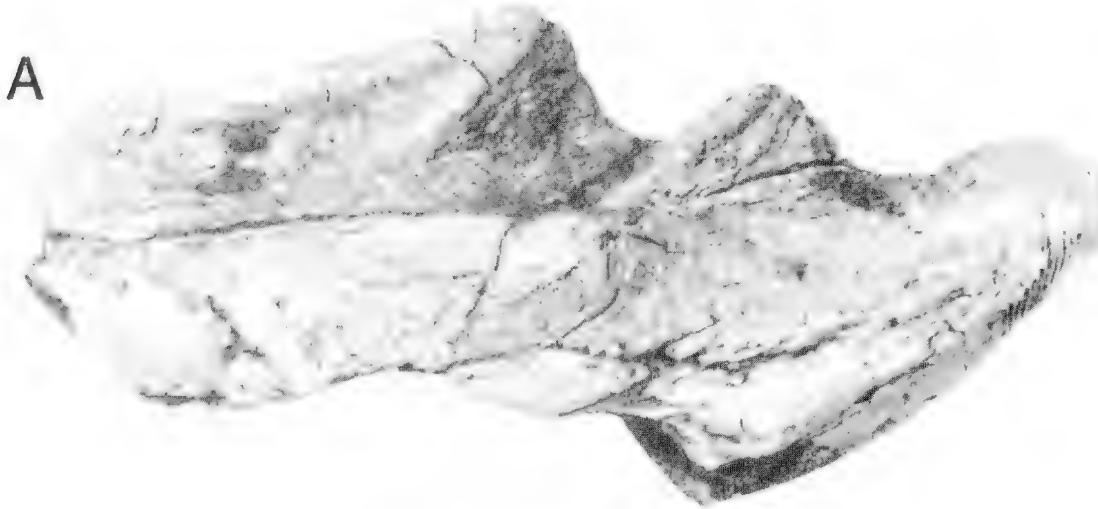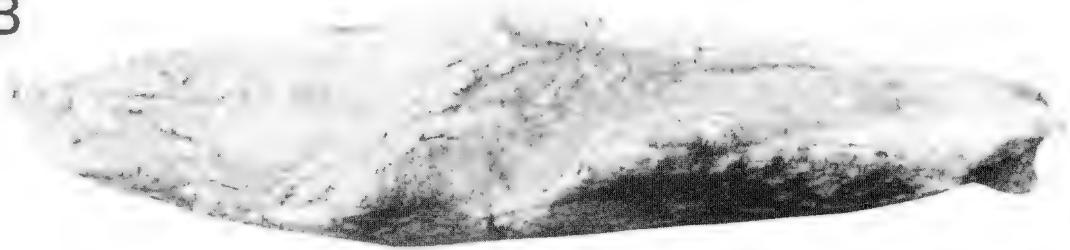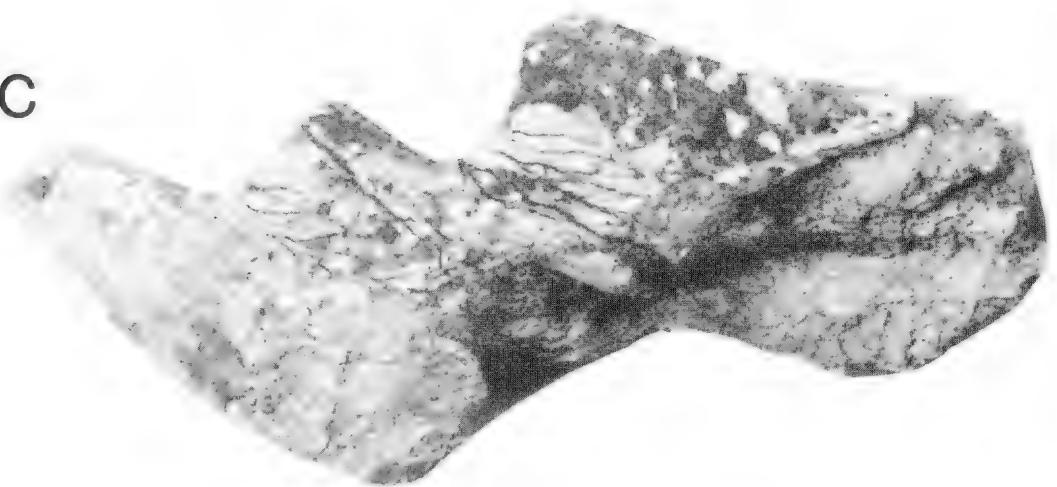
Fig. 1. *Edaphodon eyrensis* sp. nov. Holotype, SAM P24770. Aptian Bulldog Shale, South Australia. A, oral view; B, oral margin; C, aboral view. Natural size.

lateral tritor (LMT) is situated ventral to the mesial tritor and in cross-section is disposed with its long axis at right angles to the mesial tritor. The exposed anterior end of the lateral median tritor narrows to a point. The symphysial tritor (ST) is broader anteriorly than the other tritors, but is relatively thin in cross-section. Although the aboral surface is poorly preserved it is strongly convex anteriorly becoming flatter in the posterior half. The symphysial facet (sf) is broadest posteriorly, with the ventral margin being gently curved.

Discussion

Toothplates of chimaerids show a wide range of shapes and tritorial arrangements which led early workers to confuse various genera and species (Hussakoff, 1912). A series of mandibular toothplates of *Edaphodon mirificus* Leidy, 1856 from the Cretaceous of North America show changes attributable to growth and intraspecific variation. With increasing age the mandibular beak becomes broader and the median lateral tritor becomes more posteriorly situated (Hussakoff,
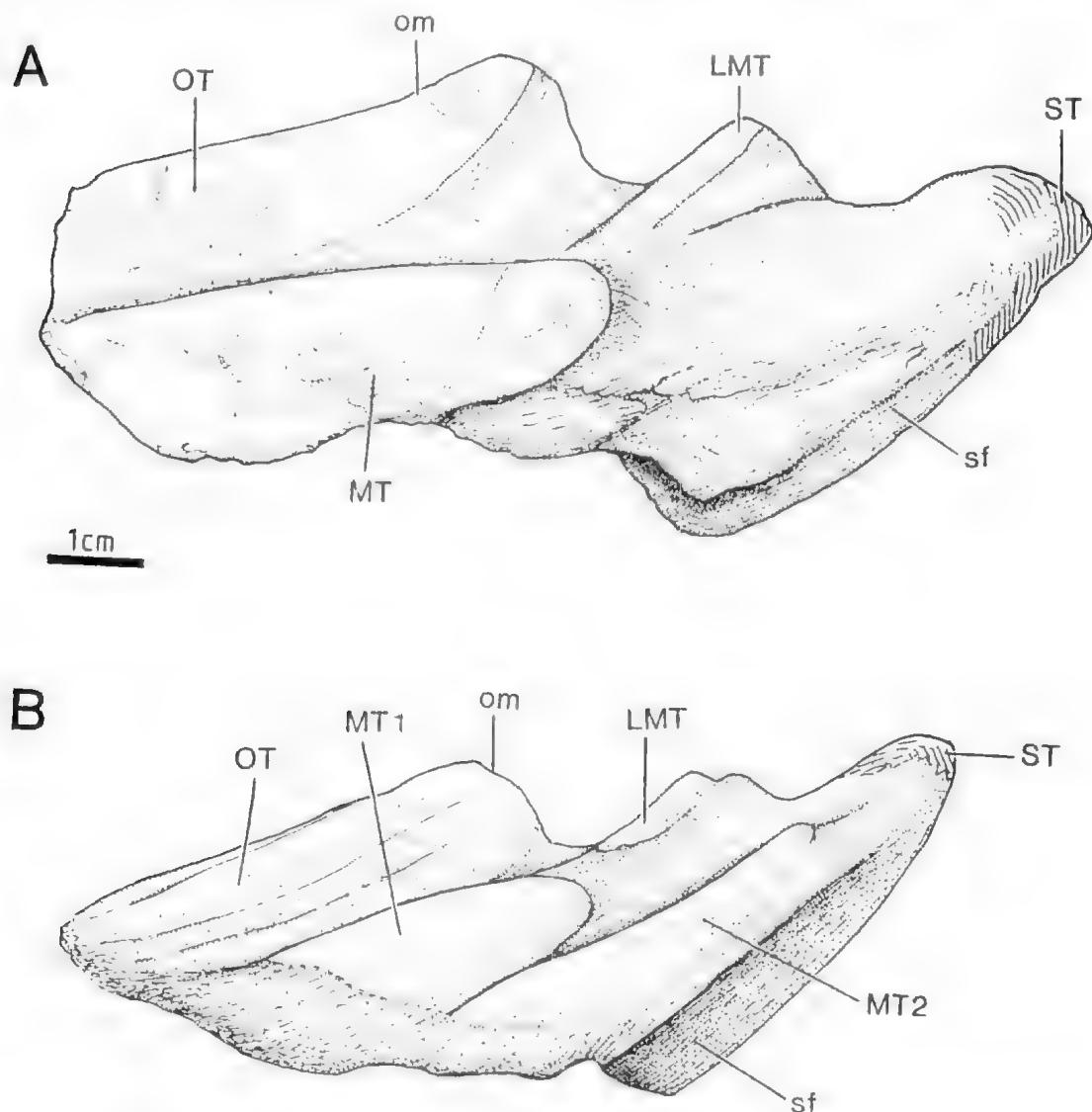
Fig. 2. A, *Edaphodon eyrensis* sp. nov., Cretaceous, South Australia. Holotype in oral view. B, *E. sweeti* Chapman & Pritchard, Miocene, Victoria. Composite restoration of left mandibular toothplate based mainly on NMV P160769. LMT, lateral median tritor; MT, MT1, MT2, mesial tritor; OM, oral margin; OT, outer tritor; sf, symphysial facet; ST, symphysial tritor.

1912, Fig. 6). This indicates that the basis for comparing the mandibular toothplates of different species relies on overall shape and the relative size and position of all the tritors. Tritors are often damaged or worn on fossil toothplates and therefore some variation in the shape of exposed tritorial surfaces is expected (Fig. 3).
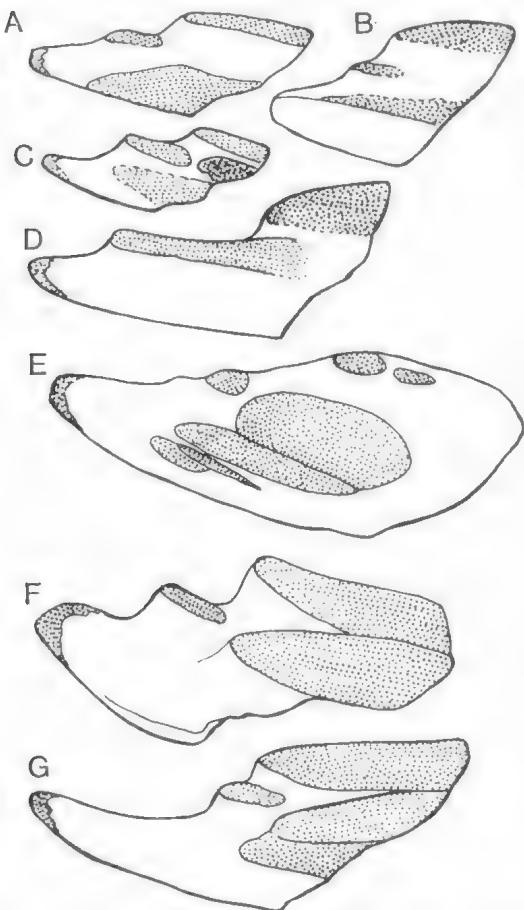
Fig. 3. Comparison of mandibular toothplates for various species of *Edaphodon*. A, *E. mirificus*; B, *E. stenobryus*; C, *E. agassizi*; D, *E. latigerus*; E, *E. bucklandi*; F, *E. eyrensis* sp. nov; G, *E. sedgwicki*. A-D, G from Hussakoff, 1912. E from Casier, 1966. Not to scale.

The other Australian species of *Edaphodon* are *E. sweeti* Chapman & Pritchard, 1907 and *E. mirabilis* Chapman & Cudmore, 1924 both from the Miocene and Pliocene of Victoria. Fig. 2 shows a comparison between *E. eyrensis* and *E. sweeti*. The mandibular toothplates of *E. sweeti* described by Chapman & Pritchard (1907) were not complete, but good material has since been found from the Pliocene Grange Burn Coquina, Victoria, and the

shape of the toothplate and arrangement of tritors can be restored (NMV P160769). *E. sweeti* differs from *E. eyrensis* in having a composite outer tritor with 3-4 bony ridges dividing it; two large mesial tritors, more slender form, and proportionately longer symphysial facet. The oral margin is quite angular, as in *E. eyrensis*, but anteriorly the symphysial beak is more elongated and is concave on the aboral surface. *E. mirabilis* is known only from palatine toothplates, which have a long, slender form but are quite robust in overall structure (Chapman & Cudmore, 1924). It is unlikely that the short mandibular toothplate of *E. eyrensis* belongs with this type of palatine plate.

Edaphodon eyrensis has a broader, shorter mandibular toothplate than most species (Fig. 3), except for *E. stenobryus* Cope 1875, from the Cretaceous of North America, which has a breadth/length ratio around 0.7 (Fig. 3b). Some species from the Cretaceous of Europe and North America also have rostrally produced beaks (*E. sedgwicki* Agassiz 1843, *E. latigerus* Cope 1869; Fig. 3D, G; *E. mantelli*, Woodward, 1912). In the development of large, almost equidimensional outer and mesial tritors *E. eyrensis* resembles *E. sedgwicki* (Fig. 3G), which is the only other species older than *E. eyrensis* as it occurs in the Neocomian of England (Hussakoff, 1912). This would suggest that the simple tritorial arrangement of these two species is a primitive pattern for the genus.

Younger species have mandibular toothplates in a variety of forms with many having additional tritors present (e.g. *E. bucklandi*, *E. agassizi*, *E. sweeti*). All of the *Edaphodon* dentition types stem from the primary strengthening of the mandibular symphysis by the widening of the symphysial facet, which characterises the genus. Extreme thickening of the mandibular symphysis and robustness of the toothplates is seen in the Upper Jurassic *Pachymylus* (Woodward, 1892), a possible precursor to the line of *Edaphodon*.

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DISTRIBUTION OF LERISTA TERDIGITATA (SAURIA: SCINCIDAE) IN SOUTH AUSTRALIA

BY T. D. SCHWANER, A. EDWARDS & B. MILLER

Summary

Many recent new distributional records for reptiles in South Australia reflect inadequate field surveys and poor documentation of the state's herpetofauna. Here we report a significant range extension of the fossorial, scincid lizard, Lerista terdigitata (Parker, 1926) in South Australia.

DISTRIBUTION OF *LERISTA TERDIGITATA* (SAURIA: SCINCIDAE) IN SOUTH AUSTRALIA

Many recent new distributional records for reptiles in South Australia[1,2,3] reflect inadequate field surveys and poor documentation of the state's herpetofauna. Here we report a significant range extension of the fossorial, scincid lizard, *Lerista terdigitata* (Parker, 1926), in South Australia.

The range of *L. terdigitata* was "islands, coast and hinterland of the Great Australian Bight"[4] (Fig. 1). However, specimens recently collected from near Billa Kalina Hstd, 29°55'S, 136°11'E (SAM R20991-92, R21022), and from the Mt Morris foothills, near Amata aerodrome, 26°08'S, 131°05'E (R25883), in the Musgrave Ranges in the far north-west of S. Aust., extend the distribution of *L. terdigitata* about 600 km N of its previously recognized range.

Although the Mt Morris specimen (a male, SVL = 51.5 mm, TL = 64.0 mm) has the normal scalation of *L. terdigitata* from more coastal localities[4,5] the pattern is markedly different (Fig. 2). Bold stripes replace the longitudinal series of spots on the dorsum, and much larger spots (not flecks) are found on the venter. Specimens from Billa Kalina Hstd are patterned like the coastal forms. Thus, it is not known whether there is a grade of patterns between the two populations.

The occurrence of *L. terdigitata* in the Musgrave Ranges suggests that the species also may be found in adjacent areas of the Northern Territory and Western Australia. The presence of yet another distributional record in the extreme northwest of S. Aust.[2,3] illustrates the need for herpetofaunal surveys in this region.

Fig. 1. Distribution of *Lerista terdigitata*. Area under the dashed line in the inset denotes the previously recognized range of the species in Australia. Solid circles denote S.A. Museum specimens.

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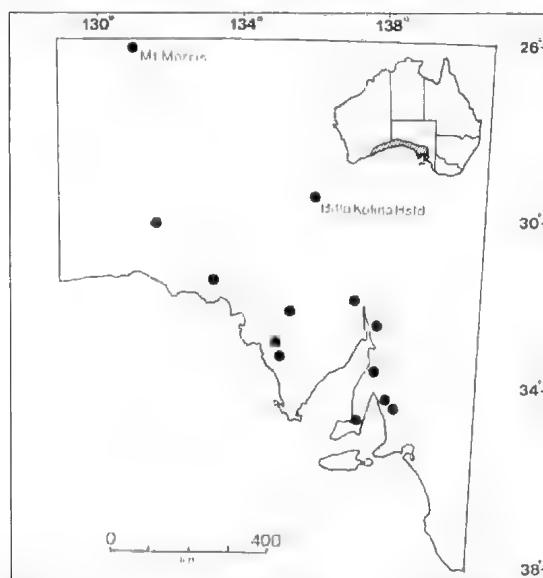
Fig. 2. *Lerista terdigitata,* (R20992, upper) from Billa Kalina Hstd, and (R25883, lower) from Mt Morris.

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TIDES OF THE ONKAPARINGA ESTUARY, SOUTH AUSTRALIA

BY J. A. SMITH

Summary

The Onkaparinga estuary is situated approximately 30 km south of Adelaide on Fleurieu Peninsula, and extends some 10.5 km from its mouth at Pt Noarlunga on Gulf St Vincent to the township of Old Noarlunga. In recent times the estuary has come under renewed interest as a recreation site which has led to the dredging of sections in Pt Noarlunga. There is, however, some concern for the environmental effects of extending these works to other regions.

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During the period May to July 1983 two pressure sensing tide gauges were deployed in the estuary (Fig. 1), one 500 m upstream from the mouth (A) and the other 1 km downstream from the head (B). This enabled a continuous record of levels to be obtained at each end of the estuary over this period (Fig. 2). Water heights were taken from each record at hourly intervals and used to derive tidal constants by a least squares fit technique. The estuary constants were then used in a comparison with constants derived for Pt Adelaide (Outer Harbor) using data from the same observation period.

The constants for the four major primary constituents (Table 1) show a general decrease in amplitude and increase in phase lag as the tidal wave progresses from the gulf

Fig. 1. Onkaparinga Estuary, South Australia; A, Site of tide gauge near mouth; B, Site of tide gauge near head; C, Shallow region. Mean river depth given in m. (0.4–2.5).
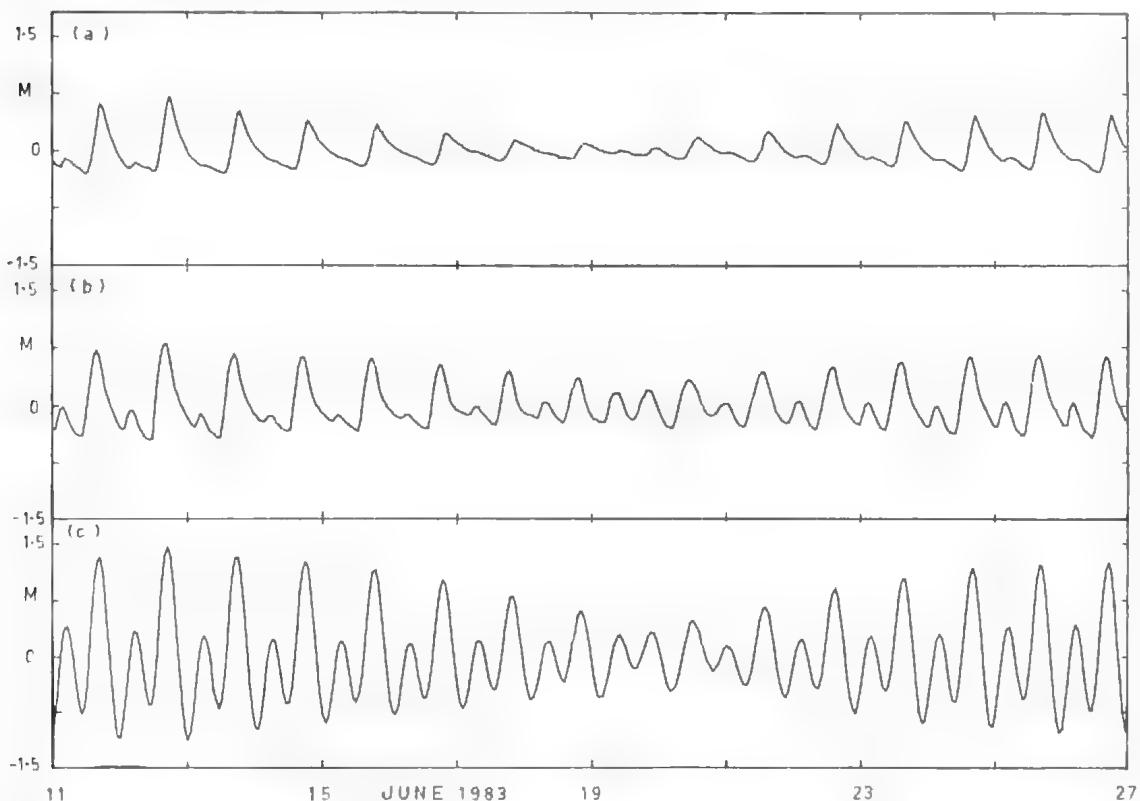

Fig. 2. Water levels for period 11th–27th June 1983; (a) Old Noarlunga (B in Fig. 1); (b) Port Noarlunga (A in Fig. 1); (c) Port Adelaide (Outer Harbor).

and up the estuary. On the other hand the two major secondary (shallow water) constituents show an increase in amplitude and no obvious trend in the phase lag under the same conditions.

TABLE 1. *Tidal constituents for the Onkaparinga Estuary and Port Adelaide.*

CONSTITUENT	GULF[1]		MOUTH[2]		HEAD[3]	
	A	g	A	g	A	g
O1	17.3	19.1	11.8	69.0	9.8	94.3
K1	25.7	47.3	17.8	82.5	12.7	121.1
M2	51.7	106.0	19.8	124.1	11.1	176.1
S2	50.0	173.2	19.0	190.4	12.8	248.0
MK3	0.7	158.6	3.9	97.4	4.2	243.4
MS4	0.1	24.4	4.1	258.1	2.5	360.0

[1] Pt Adelaide (Outer Harbor); [2] Pt Noarlunga (A on Fig. 1); [3] Old Noarlunga (B on Fig. 1) A Amplitude of tidal constituent (cm) g Phase lag of tidal constituent (°).

The times for these constituents to travel the length of the estuary were also calculated from the respective phase differences, (Table 2), and found to be similar for the primary constituents. The values were, however, much larger than expected for progression with a shallow water wave speed ($\sqrt{gH}$, where g is the acceleration of gravity and H the mean water depth),[1] and demonstrated the importance of friction in the estuary system.

TABLE 2. *Wave travel times*

CONSTITUENT	g_B-g_A	T.T.
O1	25.3	1.81
K1	38.6	2.57
M2	52.0	1.79
S2	57.6	1.92

g_B-g_A The phase difference between stations A and B (°), T.T. The wave travel time = g_A-g_B (hrs), σ The wave speed (°/msh).
σ

This observation prompted a theoretical study using a finite difference numerical model to simulate the estuary flow.[2]

The results from the simulation suggest that the region extending from 1.5 to 2.5 km upstream from the mouth forms a critical section (C in Fig. 1) with respect to the tidal propagation. This is a particularly shallow region of the estuary with only a narrow channel connecting the deeper waters up and downstream at low tide, and with parts exposed even at high tide. Flow within this section appears to be largely friction dominated and, although it forms only 10% of the estuary length, it accounts for > 60% of the wave travel time and > 30% of the wave attenuation. The model results also indicate that the head of the estuary has mean water level approx. 7 cm higher than the mouth—also due mainly to the frictional effects in this very shallow section.

On the basis of these results several predictions can be made about the possible effects of further works in the estuary. In particular, dredging in regions other than the critical section discussed above would probably have little effect on the water flow or levels in the estuary, but even minor changes to this critical section would result in significant changes to the water movements. For example, in one particular model run this section was 'numerically' deepened by extending the already dredged channel downstream through this region. The results indicated this would increase the tidal range by > 20%, decrease the travel time by > 30% and decrease the mean water level at the head by 3–4 cm. Although these changes do not appear great, the increased tidal range with its associated stronger tidal currents and lower, low tide (decreased by 15 cm at the spring tide) could have damaging effects on the seagrass and other vegetation that presently exists in the estuary.

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ADDITIONS TO THE FISH FAUNA OF SOUTH AUSTRALIA

BY C. J. M. G*LOVER*

Summary

Four marine species (Pristis sp., Ophisurus serpens, Hyporhamphus regularis regularis, Scorpis lineolatus) are recorded from South Australia for the first time. A freshwater species (Amniataba percoides) is recorded from the State for the first time on the basis of a known collection.

ADDITIONS TO THE FISH FAUNA OF SOUTH AUSTRALIA

Four marine species (*Pristis* sp., *Ophisurus serpens*, *Hyporhamphus regularis regularis*, *Scorpis lineolatus*) are recorded from South Australia for the first time. A freshwater species (*Amniataba percoides*) is recorded from the State for the first time on the basis of a known collection.

Three of the marine species are essentially temperate water forms whose presence in South Australian waters is probably permanent. The occurrence of the other warm water species (*Pristis* sp.) is unexpected and it evidently constitutes a vagrant (see earlier reports[1]).

Amniataba percoides has been recorded widely in inland waters of northern Australia. It was listed for South Australia in the 1920's[2,3], but that record was neither confirmed by any known collection nor sustained by subsequent authors.

All specimens are deposited in the South Australian Museum (SAM).

Fig. 1. Snout of *Pristis* sp. (*P. zijsron* ?). SAM F2064 TL (total length) 399 mm

Family Pristidae. *Pristis* sp. (probably *P. zijsron* Bleeker, 1851).

The rostral process (Fig. 1) of a specimen caught 16 km offshore from Glenelg, (approx. 34° 59′S, 138° 20′E), in 1936, by E. G. Kelly, is registered in the South Australian Museum. The intact specimen would have been about 1 300 mm total length.

The rostral process has 29 pairs of teeth. This is consistent with that of *P. zijsron*, one of the three pristid species recorded in Australian waters[4].

Pristids are found mainly in the world's tropical and sub-tropical waters[5]. In Australian *P. zijsron* has been recorded in coastal, estuarine and fresh inland waters of Queensland, New South Wales and western and northern Western Australia[4,6]; its range reportedly extends to the East Indies, India and Sri Lanka[7].

The present record is the first for the family Pristidae from Australia's southern waters.

Fig. 2. *Ophisurus serpens*. SAM F4566. TL 885 mm.

Family Ophichthidae. *Ophisurus serpens* (Linnaeus, 1758).

A specimen (Fig. 2) was collected from a rock pool at Coobowie (approx. 35° 03′S, 137° 44′E), on 7.i.1970, by M. J. Stanton

O. serpens has been recorded previously in Australia from off N.S.W., Victoria, Tasmania and W.A.[8]. It is recorded elsewhere in the Indo-Pacific and eastern Atlantic Oceans, and in the Mediterranean[9].

Family Hemiramphidae. *Hyporhamphus regularis regularis* (Günther, 1866)

Fifteen specimens (SAM F4803) were netted in Angas Inlet, off the Port River (approx. 34° 48′S, 138° 32′E), on 30.viii.1984, by S. Aust. Dept of Fisheries officers. Two additional specimens (Fig. 3) were hooked at the same locality on 23.ix.1984 by T. E. Lloyd.

H. regularis occurs only around the southern half of the Australian continent, where it has been recorded from southern Qld, N.S.W., Vic. and south-western W.A.[10]. Two distinct sub-species are recognised, one on the continent's south-east coast (*H. regularis ardelio*), the other on its south-west coast (*H. regularis regularis*)[10].

M. F. Gomon advised me (pers. comm., 1984) that the S. Aust. specimens are *H. regularis regularis*. This record therefore represents the most easterly documented occurrence of the western sub-species.

Fig. 3. *Hyporhamphus regularis regularis*. SAM F4831 TL 255 mm (smallest specimen)
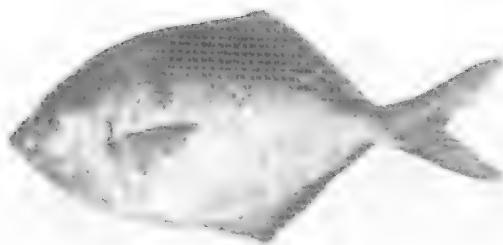
Fig. 4. *Scorpis lineolatus.* SAM F4761. TL 316 mm.

Fig. 5. *Amniataba percoides.* SAM F4792. TL 54 mm (largest specimen).

Family Scorpidae. *Scorpis lineolatus* Kner, 1865.

Two specimens were captured by speargun between Victor Harbor and Seal Island (Seal Rock), (approx. 35° 34'S, 138° 38'E), on 31.xii.1983, by competitors in a national spearfishing competition. One specimen is illustrated (Fig. 4): the other is SAM F4762.

S. lineolatus has been recorded only in Australia, from Qld, N.S.W., Vic., Tas. and at Lord Howe Island.[8].

The present S. Aust. record represents the species' most westerly documented occurrence.

Family Teraponidae *Amniataba percoides* (Günther, 1864).

Two specimens (Fig. 5) were netted at the Neales River crossing on the main road south-east of Oodnadatta

(approx. 27° 54'S, 135° 46'E), on 3.v.1984, by a South Australian Museum party.

A. percoides is endemic to Australia where it is recorded widely dispersed in inland waters of Qld, Northern Territory and W.A.[11,12]. An early record from S. Aust.[2,3] was not substantiated by any hitherto known collection.

The present record is the species' most southerly documented occurrence[12,13].

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STUDIES ON SOUTHERN AUSTRALIAN ABALONE (GENUS HALIOTIS) V. SPAWNING, SETTLEMENT AND EARLY GROWTH OF H. SCALARIS

BY S. A. SHEPHERD, P. S. CLARKSON & J. A. TURNER

Summary

This note describes the spawning cycle of Haliotis scalaris Leach and the settlement density and growth of juveniles of the species at West Island (35°37′00′′S, 138°35′00′′E), South Australia. This spawning cycle differs markedly from that previously described for the species at Tiparra Reef, South Australia and is therefore of considerable interest.

STUDIES ON SOUTHERN AUSTRALIAN ABALONE (GENUS *HALIOTIS*) V. SPAWNING, SETTLEMENT AND EARLY GROWTH OF *H. SCALARIS*

This note describes the spawning cycle of *Haliotis scalaris* Leach and the settlement density and growth of juveniles of the species at West Island (35°37'00"S, 138°35'00"E), South Australia. This spawning cycle differs markedly from that previously described for the species at Tiparra Reef[1], South Australia and is therefore of considerable interest.

Samples of 9-12 sexually mature female *H. scalaris* 65-80 mm long were collected at Abalone Cove, West I., at about monthly intervals from February 1983-July 1984. The entire visceral mass was preserved in 10% formalin and sea-water and later sectioned in the laboratory. Cross-sections of the gonad and digestive gland were traced on transparent plastic, the cut-out sections weighed, and the respective areas of gonad and digestive gland calculated. A gonad index was then calculated with the formula Gonad index = 100 (Area of gonad)/(Total area of section). The annual reproductive cycle of this species at West I. proved to be synchronous within the population so that measurement of oocyte-ova diameters to distinguish the stages of the reproductive cycle was unnecessary (see Shepherd & Laws[1] for details of the method).

Sea surface temperature data were obtained with a mercury thermometer at about monthly intervals at West I.

A hand lens, designed for use underwater with about 3× magnification (the optics are described by Shepherd & Turner in prep.) was used to search for *H. scalaris* on crustose coralline algal substrate, the preferred substrate for settlement of this species (Shepherd & Turner in prep.). Searches were done for 60-100 minutes at about monthly intervals in the boulder habitat at West I. at 4-5 m depth and the lengths of all individuals to about 25 mm long recorded to 0.1 mm.

Changes in the mean monthly gonad index of *H. scalaris* from February 1983-May 1984, together with sea surface temperature data are given in Fig. 1. The index increases from winter to mid-summer and declines abruptly from late summer through the autumn. The increase indicates maturation and increase in size of oocytes in the gonad, and the decline of the index indicates the onset of synchronous spawning in the population. Spawning appears to have commenced later in 1983 than in 1984 and to have been more complete. In 1984 the gonad never became completely spent but commenced to increase in size again in July.

Thus *H. scalaris* has a late summer to autumn spawning season (February-May) which is synchronous throughout the population, and appears to begin at about the time of maximum summer sea temperature. This spawning cycle contrasts strikingly with the asynchronous cycle of *H. scalaris* at Tiparra Reef where spawning potentially occurs throughout the year.
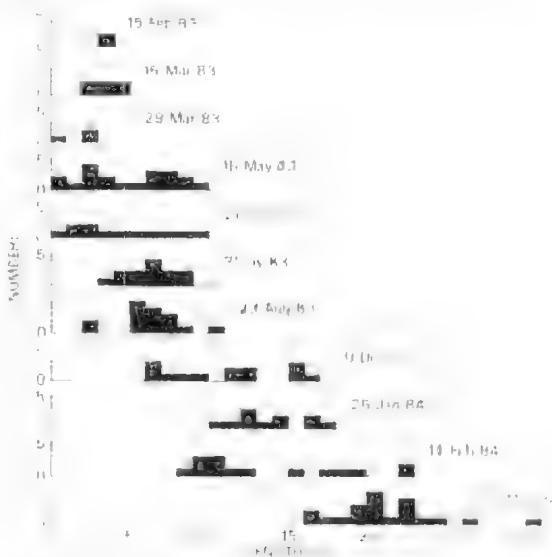
Fig. 2. Length frequency distributions for *H. scalaris* at West Island from February 1983 to May 1984.

Of the various environmental factors that are known to influence the spawning cycles of abalone e.g. temperature,[2] photoperiod,[3] and food abundance[3,4] only the latter shows a marked difference between the two sites. Drift food algae are seasonally in short supply at Tiparra Reef but abundant throughout the year at West I.,[5] but this is unlikely to account for the differences in spawning between the sites. Further studies of *H. scalaris* are necessary, especially in other parts of its geographic range, to elucidate the problem. *H. rubra* Leach also shows marked, but unexplained, differences in spawning cycle between these two sites.[1] The only other abalone species that we know of with a similarly variable spawning cycle between localities is *Haliotis rufescens* Swainson.[6,7]

Fig. 1. (upper) — mean monthly sea surface temperatures (smoothed curve); (mid) — monthly distribution of gonad indices with standard errors; (lower) — density of small *H. scalaris* ≤5 mm at study site.

The density of small *H. scalaris* (measured in mean numbers of individuals ≤5 mm recorded per 15 min searching time is given in Fig. 1. Maximum settlement apparently occurred in March 1983. The relatively high densities recorded from July to September 1983 are of larger individuals (3–5 mm) and do not indicate recent settlement.
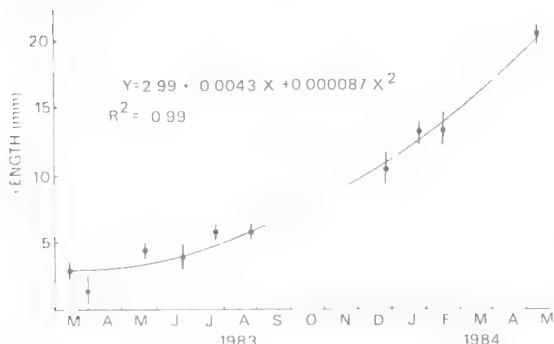
Fig. 3. Plot of mean length (with standard errors) of 1983 cohort of *H. scalaris* from March 1983 to May 1984. A polynomial regression of best fit to the means is shown.

Length frequency data from February 1983–May 1984 (Fig. 2) show that very small *H. scalaris* (1–3 mm long) were present from February–June 1983 indicating settlement in that period. This is in good agreement with the spawning season described above. No small *H. scalaris* were found in the 1984 spawning season, suggesting settlement was very poor and not detectable.

Shepherd (in prep.) associated the similar poor recruitment of *H. laevigata* Donovan at West I. in 1984 with the lower maximum summer sea temperature in 1984 compared with 1983. The settlement failure of *H. scalaris* in 1984 may also be associated with lower summer sea temperatures in that year or with the incomplete spawning or a combination of them.

The change in mean size of the 1983 cohort from March 1983–May 1984 (Fig. 2) enables an estimate to be made of the growth of the cohort in the first year. The equation of best fit empirically fitted to the data is given in Fig. 3. On the basis that settlement occurred between 1 February and 30 June 1983, a mean birth date for the cohort can be fixed at 15 April 1983. From the regression (Fig. 3) the mean length of the one year old animal is therefore about 18.5 mm. Comparison of this growth rate with that of other haliotids[8] suggests that it is relatively rapid for a species whose maximum size (at West I.) is only about 100 mm.

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Contents

A NEW SPECIES OF CRUSTACEAN (SYNCARIDA: ANASPIDACEA: KOONUNGIDAE), FROM SINKHOLES AND CAVES IN THE SOUTH-EAST OF SOUTH AUSTRALIA

BY WOLFGANG ZEIDLER

Summary

A new species of syncarid crustacean, Koonunga crenarum sp. nov. is described from sinkholes and caves near Mt Gambier, South Australia. The species occurs in surface vegetation and to a depth of 40 m. Superficially the new species resembles K. cursor but females are at least twice as large, reaching lengths exceeding 20 mm; the sternal process of the male petasma lacks a posterior projection and the eyes are absent. A brief description of the development of the male petasma and sensory organ on the antennule is given.

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by WOLFGANG ZEIDLER*

Summary

ZEIDLER, W. (1985) A new species of crustacean, (Syncarida: Anaspidacea: Koonungidae), from sinkholes and caves in the south-east of South Australia. *Trans. R. Soc. S. Aust.* 109(3), 63-75, 29 November, 1985.

A new species of syncarid crustacean, *Koonunga crenarum* sp. nov. is described from sinkholes and caves near Mt Gambier, South Australia. The species occurs in surface vegetation and to a depth of 40 m. Superficially the new species resembles *K. cursor* but females are at least twice as large, reaching lengths exceeding 20 mm; the sternal process of the male petasma lacks a posterior projection and the eyes are absent. A brief description of the development of the male petasma and sensory organ on the antennule is given.

KEY WORDS: Syncarida, Anaspidacea, *Koonunga crenarum* sp. nov., South Australia, taxonomy.

Introduction

In Australia, anaspidid syncarid crustaceans are known to occur throughout Tasmania and Victoria and an interstitial species, *Psammaspides williamsi*, has been found in the New England area of New South Wales (Schminke 1974). The Tasmanian fauna is relatively diverse and to date eight species have been described. Most of mainland Australia, however, is too arid to support anaspidid syncarids and besides *P. williamsi* the only other described species are *Koonunga cursor* Sayce, 1908 and *Stygocarls giselae* Schminke, 1980. Several undescribed species of *Koonunga* are known to occur in Victoria (Drummond 1959) and also on King Island and in north-western Tasmania (Williams, W. D. 1974). It is likely that more species remain to be discovered as aquatic habitats are surveyed in more detail. *K. cursor* occurs sporadically throughout southern Victoria, usually in small permanent or semi-permanent swamps and in pools in streams which flow only after heavy rains (Drummond 1959) and it has recently been recorded from similar habitats in north-western Tasmania (De Deckker 1980). *S. giselae* is an interstitial species and is only known from the type locality, Battle Point, Tambo River, Victoria (Schminke 1980).

The species described here was found in sinkholes and caves in the Mt Gambier area, South Australia (Fig. 1). It was first recorded by Zeidler (1983) being the first record of a syncarid from South Australia. It belongs to the family Koonungidae and superficially resembles *K. cursor*.

Materials and Methods

Specimens were collected from a number of sinkholes and caves in the south-east of S. Aust

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(Fig. 1) with a hand net from amongst algae and aquatic plants near the surface or by entrapment in a glass jar while scuba diving. The "L" number given with each locality refers to the identification number used by the Cave Exploration Group of South Australia to distinguish each cave and sinkhole in the lower south-east. A total of 236 specimens (60 ♂ and 176 ♀) were collected and examined.

Specimen length is measured from the tip of the rostrum to the tip of the telson. Specimen width is measured as the width of the third pleonite segment (usually the widest segment). Pleon length excludes the telson as the limit of the telson is obscured by spines.

Material reported here is deposited in the South Australian Museum, Adelaide (SAM), Australian Museum, Sydney (AM), Museum of Victoria, Melbourne (NMV) and the Tasmanian Museum and Art Gallery, Hobart (TM). All of the specimens are preserved in 75% alcohol or 2% formaldehyde/propylene glycol solution. Of the types only the holotype, allotype and paratype ♂ (SAM C3992) have been dissected (partially) and dissected appendages have been preserved with the carcass.

The following abbreviations are used in the text. Mxp. = maxilliped (thoracopod 1), P 1-7 = pereopods 1-7 (thoracopods 2-8), Pl 1-5 = pleopods 1-5, LHS = left hand side and RHS = right hand side when viewed dorsally.

Koonunga crenarum sp. nov.
FIGS 2-7

Holotype: SAM C3989 (♀), collected amongst surface algae and aquatic plants in unnamed sinkhole known as "Fossil Cave" (L81), approx. 3.3 km SE of Tantanoola Caves on Princes Hway, S. Aust. by W. Zeidler, 1.iii.1982.

Allotype: SAM C3990 (♂), collected from same locality by P. Horne, 8.iii.1981.

Paratypes: SAM C3992 (♂) collected P. Horne, 8.iii.1981, same locality; SAM C3991 (♀), AM P35067 (♀), P35068 (♂), NMV J10809 (♀), J10810 (♂), IM G2848 (♀), G2849 (♂) collected by W. Zeidler, 1.iii.1982, from same locality.

Other material examined: SAM C3993 (11 ♀'s), collected from type locality, at 10 m depth by P. Horne, 26.i.1981; SAM C3994 (15 ♀'s), from type locality, P. Horne, 8 iii.1981; SAM C3995 (20 ♀'s), from type locality, W. Zeidler, 1.iii.1982; SAM C3996 (83 ♀'s, 45 ♂'s), from type locality, W. Zeidler and K. L. Gowlett, 16.vii.1984; SAM C3997 (1 ♀), Tank Cave (L230), just E of type locality, collected near surface by P. Horne, 6.ii.1983; SAM C3998 (1 ♂), Allendale Sinkhole (L11), centre of main road, Allendale East, approx. 20 km S of Mt Gambier, collected in total darkness at 27.5 m depth by P. Horne, 1.ii.1982; SAM C3999 (4 ♀'s), Benara Sinkhole (L32-33), near "Benara", 6 km WSW of Mt Gambier, collected at 19 m depth, by P. Horne, 12.vi.1982. SAM C4030 (1 ♀), from same locality, at 5 m depth, P. Horne, 27.xii.1984; SAM C4000 (2 ♀'s), Kilsbys Hole sinkhole (L46), approx. 0.5 km W of "Burleigh"—12 km SW of Mt Gambier, collected at 30 m depth by P. Horne, 6.ii.1983. SAM C4001 (12 ♀'s, 2 ♂'s), from same locality, at 3 m depth, P. Horne, 13.ii.1983; SAM C4002 (1 ♂), Devils Punchbowl sinkhole (L47), approx. 2 km SW of "Barnoolut"—approx. 15 km SW of Mt Gambier, collected from weed at 13.7 m depth by P. Horne, 3.iii.1981. SAM C4003 (4 ♀'s), from same locality, at 40 m depth, P. Horne, 1.iii.1981; SAM C4004 (1 ♀), Walnut Cave (L53), approx. 18 km SW of Mt Gambier and 4 km due W of Mt Schank, collected at 3 m depth by P. Horne, 20.ix.1981; SAM C4005 (2 ♀'s), Gums Road Cave (L63), approx. 4.5 km NE of Kongorong—20 km SW of Mt Gambier, collected near surface by P. Horne, 26.ix.1982; SAM C4006 (2 ♂'s), Bonlebrush Sinkhole (L64), in Caroline Forest, approx. 15 km SSE of Mt Gambier, collected at 10 m depth by P. Horne, 12.xi.1982; SAM C4007 (1 ♀), Hereford-Stream Cave (L70), approx. 6 km E of Ewens Ponds—23 km SSE of Mt Gambier, collected near surface by P. Horne, 22.xi.1982; SAM C4008 (1 ♀, 1 ♂), Mudhole sinkhole (L77), Tantanoola Forest, approx. 6 km SE of Tantanoola Caves, collected at 6 m depth by P. Horne, 31.i.1982; SAM C4009 (2 ♀'s, 1 ♂), Alleyns Cave sinkhole (L84/85), just E of Mudhole, collected near surface by P. Horne, 30.xii.1983; SAM C4010 (1 ♀), McKay Shaft sinkhole (L125), 3 km W of Valley Lake, Mt Gambier, collected at 3 m depth by P. Horne, 11.xii.1982; SAM C4011 (1 ♀), Mushroom Cave (L132), approx. 2 km E of Ewens Ponds, collected at 3 m by P. Horne, 22.ix.1982; SAM C4012 (1 ♀), unnamed sinkhole (L144), in Mt Gambier Forest, approx. 2 km NW of Mt Gambier Airport, collected near surface by P. Horne, 14.xi.1982; SAM C4013 (1 ♂, 1 ♀), The Shaft sinkhole (L158), approx. 3 km W of Allendale East, collected at 5 m depth by P. Horne, 14.iii.1984, SAM C4014 (1 ♀), from same locality, at 3 m depth, P. Horne, 4.ii.1984; SAM C4015 (1 ♀), The Bullock Hole sinkhole (L163), on "Barnoolut" property—approx. 14 km SW of Mt Gambier, collected at 27.5 m depth by P. Horne, 6.iii.1982; SAM C4027 (4 ♀'s, 1 ♂), Glencoe West Cave (L77), approx. 11 km NE of Tantanoola Caves, collected at 2 m depth by A. Cox and P. Horne, 29.xii.1984; SAM C4029 (1 ♀), Englebrects Cave (L19/20), Mt Gambier, collected at 9 m depth by A. Cox, 23.iii.1985.

Specimens have also been sighted in Morgans Cave (L34) and The Pines Cave (L61), both near

Alleyns Cave; Hells Hole sinkhole (L40) just north of Bottlebrush Sinkhole and Simpsons Hole sinkhole (L42) between Devils Punchbowl sinkhole and Gums Road Cave (Fig. 1).

Description of holotype: Female measuring 18.3 mm total length, 3.4 mm width. General appearance illustrated in Fig. 2. First thoracic somite fused with head. Percon with seven free somites and pleon with six free somites and a telson. All body somites with one pair of appendages. Anus opens at posterior limit of pleonite 6. Pleon (excluding telson) longer (7.7 mm) than percon (6.2 mm) and broader than percon and head. Head length equivalent to first 3½ pereonites, broader than pereonites 1-4, equal to pereonite 5 and narrower than pereonites 6 and 7. Pleonite 6 longest body segment, pleonites 1-3 broadest. Pleonite 6 with row of six well spaced spines near dorsal-posterior border interspersed with 1-2 fine setae. Body segments progressively more robust from anterior to posterior to about pleonite 4.

Head rectangular (3.2 × 2.8 mm) with short, pointed rostrum and distinct antero-lateral incision above attachment of antenna. Pronounced short mid-lateral transverse sulcus. Eyes absent but pigment more concentrated near antero-lateral incision.

Antennule (Fig. 4a): peduncle of three segments, outer flagellum of 56 (LHS) and 48 (RHS) segments and inner flagellum of 16 (LHS) and 15 (RHS) segments. Outer flagellum about 3.5× length of inner. Peduncle and outer flagellum as long as 3/4 body length. Basal segment of peduncle broader, almost as long as following two combined. Basal segment of outer flagellum with oblique dorsally serrated inner margin. Presence or absence of statocyst in basal segment of peduncle could not be determined with certainty.

Antenna (Fig. 4b): slightly more than 2/3 length antennule; peduncle of 4 segments and single flagellum of 35 segments (LHS & RHS). Basal segment short, segments 2-4 elongate, rectangular, segment 3 longest.

Upper lip (Fig. 3a): rows of short bristles on both sides at extremity and small central depression on aboral surface near extremity.

Mandibles (Figs 3c-f): 3-segmented palp; middle segment greatly enlarged, about twice length basal segment; terminal segment small, rounded; feathered setae along inner margin of segment 2, apically on segment 3. Base of mandibles stout, ending in well developed molar and incisor process. Molar process with small grinding surface surrounded by numerous spiniform setae. Incisor process of left mandible with seven denticles arranged in "S" shaped row, denticle nearest molar
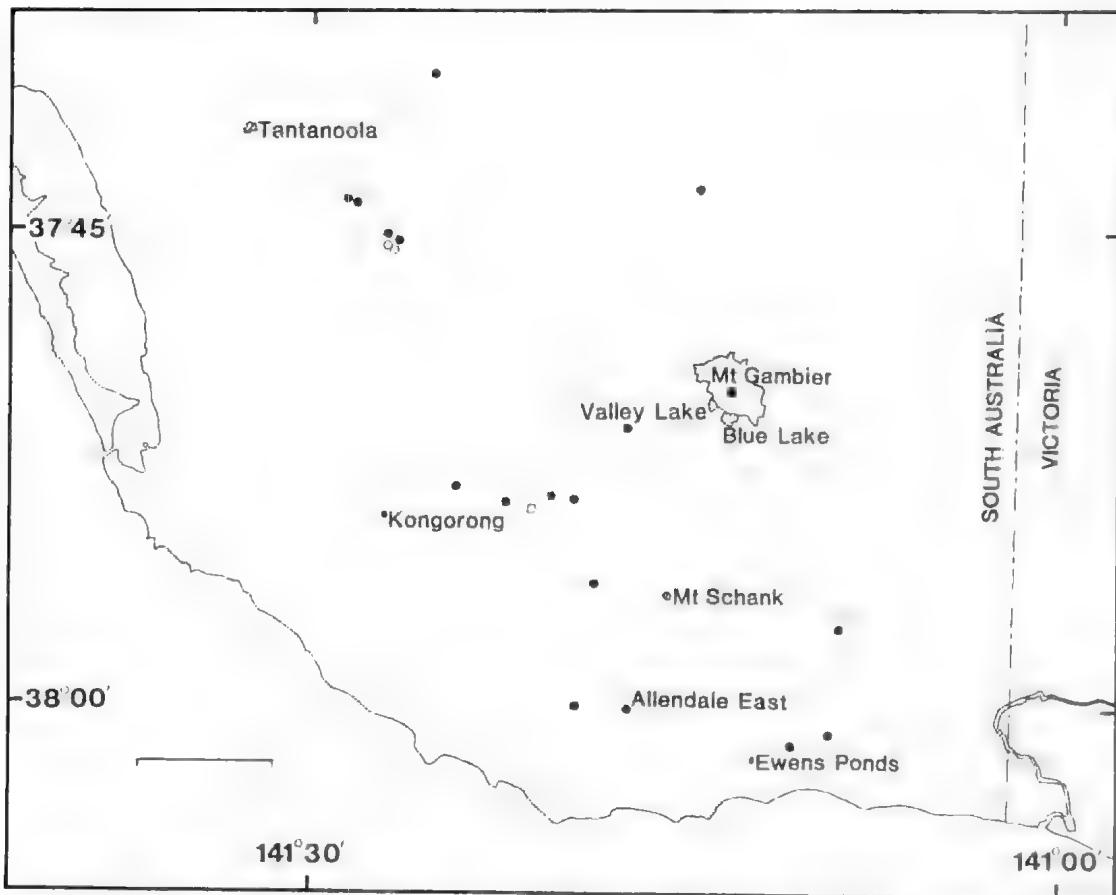
Fig. 1. Localities where *Koonunga crenarum* sp. nov. has been collected (●) or sighted (○) Scale bar - 5 km.

reduced. Incisor process of right mandible with five denticles arranged in "C" shaped row overlapping left mandible when viewed aborally. No evidence of secondary cutting plate or spine row.

Lower lip (Fig. 3b): bifid with deep central groove; inner lobes well developed; outer lobes upright almost perpendicular to aboral surface. Distal margin of lobes and part of lip covered by long setae, particularly on aboral surface.

First maxilla (Fig. 3h): two lobed. Outer lobe with small, one-segmented palp with three long, terminal spinules, partially feathered along inner margin. Extremity of outer lobe obliquely truncated with twelve strong, chitinous (?) spines, some stouter than others and two smaller feathered spines near the aboral surface. Inner lobe about 1/2 width of outer lobe with one long, stout feathered spine near oral surface surrounded by eight smaller feathered spines.

Second maxilla (Fig. 3g): smaller than first consisting of four lobes; inner one smallest, others increase successively in length and width. Inner two lobes covered with short bristles or setae. Inner lobe with six feathered spinules of varying lengths terminally. Other lobes with more numerous (>10) but similar terminal spinules which fan out laterally to oral and aboral surface.

Maxilliped (thoracopod 1) (Fig. 4c): stout limb of seven segments flexed posteriorly between merus and carpus. Coxa shorter and wider than following segments with two adjacent branchial lamellae (epipodites) near outer, aboral corner. Basis with exopodite of two joints resembling branchial lamellae along outer, aboral margin and with several fine setae near distal, oral margin. Ischium with slight expansion distally, slightly wider and longer than basis, with several long, fine setae on oral surface near inner margin and clustered on outer aboral corner. Merus inflated proximally, longer than any other segment, only slightly narrower than coxa; with long fine setae scattered over oral surface but more numerous near inner margin. Carpus, smallest joint with row of long setae along distal, oral margin for inner half and on oral and aboral
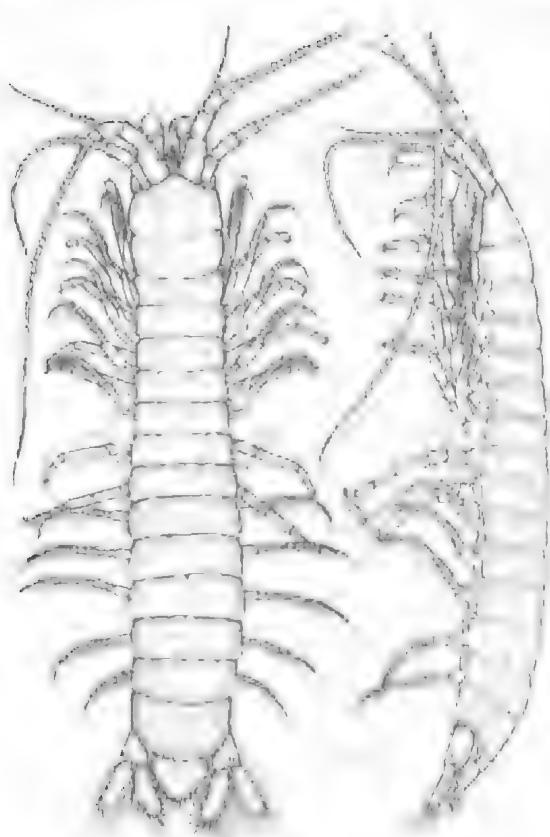
Fig. 2. *Koonunga crenarum* sp. nov. holotype ♀. Scale bar = 2 mm.

outer distal margin. Propodus robust, slightly shorter than merus, with two oblique rows of strong spines on oral surface and tuft of long setae on aboral, distal, outer corner. Dactylus small, rounded, armed terminally with one large and three smaller strong claw-like spines and few setae near inner margin.

Pereopods (thoracopods 2–8) (Figs 4f–l) similar in structure to Mxp but with basis expanded proximally, almost as wide as coxa and becoming progressively more slender with all segments more elongate. P1 slightly shorter than Mxp but slightly longer than P2 & P3 of equal length. P4 as long as Mxp and longest pereopod. P5 shortest, P6 slightly longer than P5 but slightly shorter than P2 or P3. P7 similar in lenth to P1. All pereopods flexed between merus and carpus and in backward position except for P6 which flexes inwards and P7 which flexes forwards. Coxa with setose lobe near inner, distal corner barely recognisable on P1 but progressively developed to maximum on P6 but absent on P7. P1–6, coxa with two unequal epipodites as in Mxp. P1–5, basis with multi-

segmented exopodite consisting of large basal segment reaching well past ischium and flagellum of 14–16 segments (Table 1) each segment bearing two long, feathered setae. P6, basis without expodite. P7 without epipodites or exopodite. Dactyl claws similar to Mxp but P5–7 have one additional claw. Spermatheca: two small, ovoidal plates, slightly raised from the sternum just forward of base of P7 on last pereonite (Fig. 5a).

Pleopods (Figs 5b–f): all of similar structure, lacking endopodites but with long multi segmented exopodites consisting of short-stout basal joint followed by longer more slender one and flagellum of 15 segments in Pl 1–4 and 13 segments in Pl 5, each bearing two long feathered setae. Pl 1–3 equal in length and longest pleopods. Pl 4 slightly shorter and Pl 5 shortest, about 3/4 length Pl 1–3. Pl 1–3 also flattened laterally, Pl 4 & 5 round in cross-section.

Uropods (Fig. 5h): peduncle stout, rectangular, as long as telson and almost 3/4 length pleonite 6 (measured ventrally), projecting to slightly more than 1/3 telson length; few scattered short spines on dorsal surface and near outer margin. Outer ramus almost 1 1/4 peduncle length, slightly longer than inner ramus, with long feathered setae along inner and outer margins and row of short strong upturned spines near outer dorsal margin. Inner ramus with long feathered setae along outer margin and partly terminally, remaining terminal margin with three (LHS) or four (RHS) long spines; dorsal inner margin with row of strong upward curved spines for about proximal 2/3, steadily increasing in size terminally followed by comb of smaller spines, ceasing at first terminal spine.

Telson (Fig. 5h): triangular in shape with rounded apex and slightly convex lateral margins; length (excluding spines) slightly less than width; margins with complex array of spines except for proximal 1/4, consisting of close-set fringe of short, stout spines ventrally, 20 evenly spaced, long spines directed posteriorly and about 14 slightly shorter spines directed dorsally interspersed with 1–2 fine setae.

Colour: light tan with some specimens darker than others. Those captured in deeper water and in total darkness do not vary in colour from those caught near the surface. Preserved specimens only slightly faded to date.

Description of allotype: Male measuring 14.8 mm in total length and 2.5 mm in width, essentially similar to holotype except for the following differences.

Antennule (Fig. 4c): with characteristic oval-shaped sensory organ arising from second segment of outer flagellum. Basal segment of inner flagellum saucer-shaped shielding sensory organ. Outer flagellum of
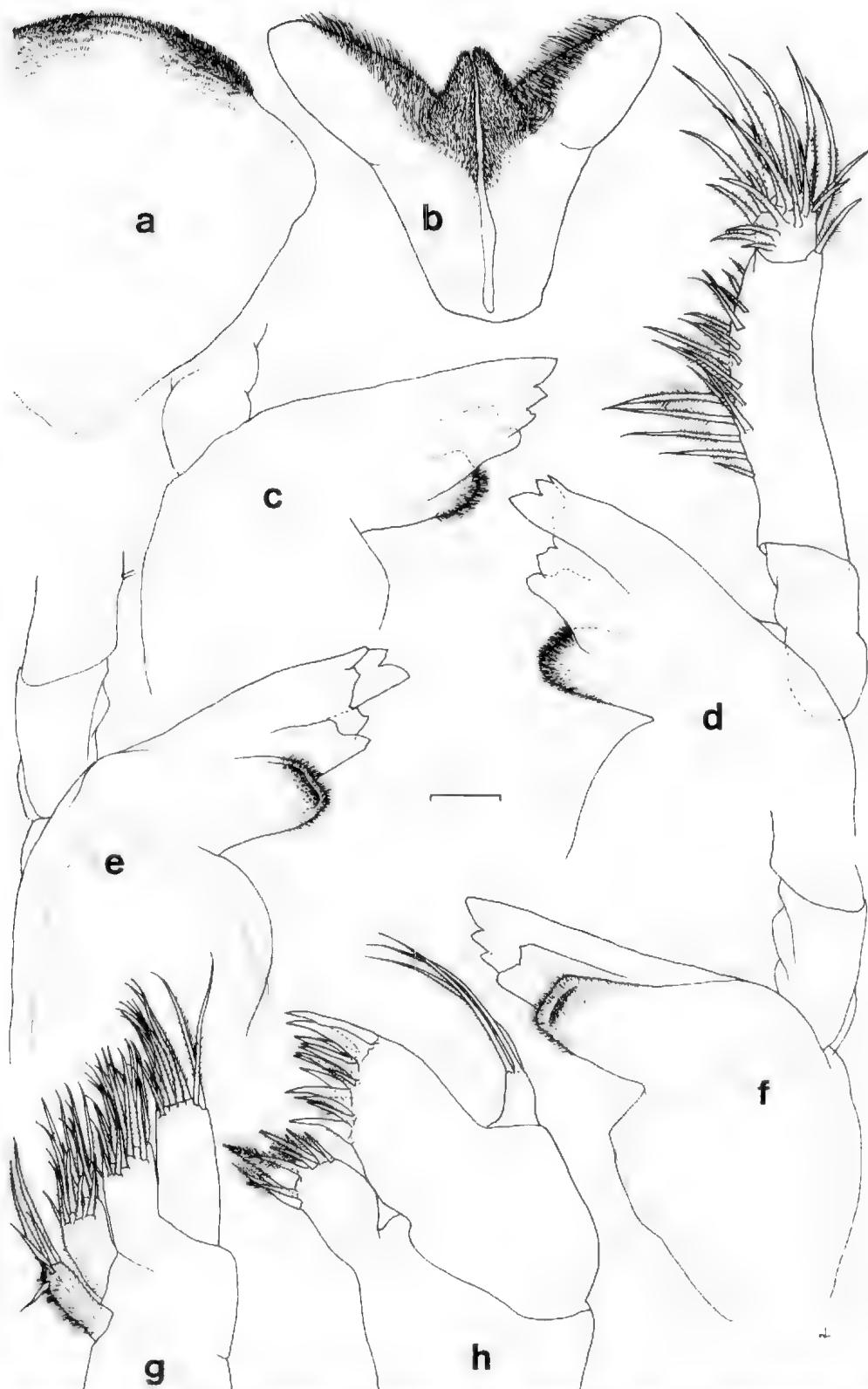
Fig. 3. *Koonunga crenarum* sp. nov. holotype ♀, mouthparts. a. upper lip; b. lower lip; c. mandible RHS, aboral view; d. mandible LHS, aboral view; e. mandible LHS, oral view; f. mandible, RHS, oral view; g. maxilla 2; h. maxilla 1; Scale bar = 0.2 mm.
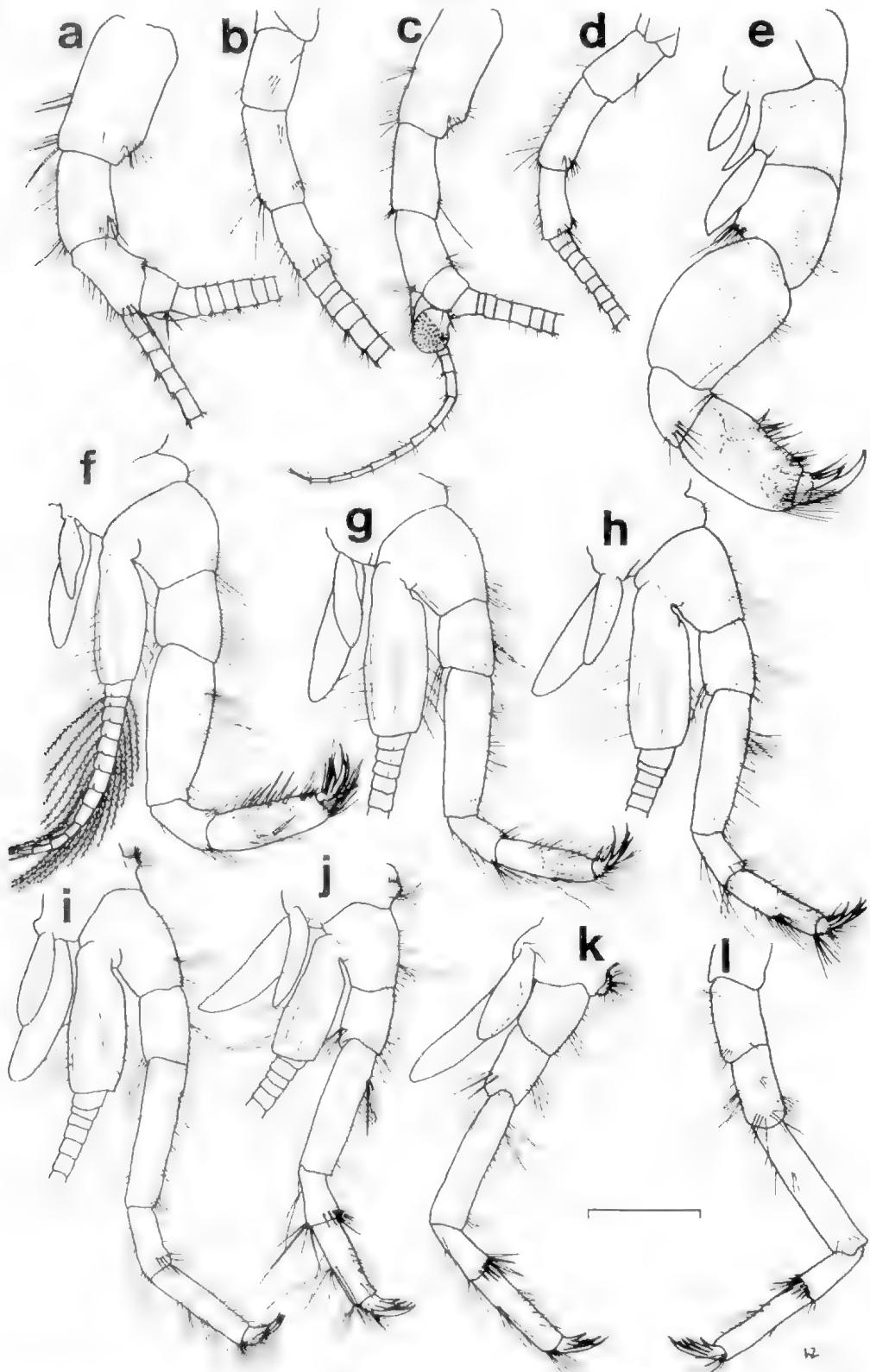
Fig. 4. *Koonunga crenarum* sp. nov. holotype ♀. a. antennule; b. antenna; c. antennule, allotype ♂; d. antenna, allotype ♂; e. Mxp; f-l = Pl-7. Scale bar = 1 mm.
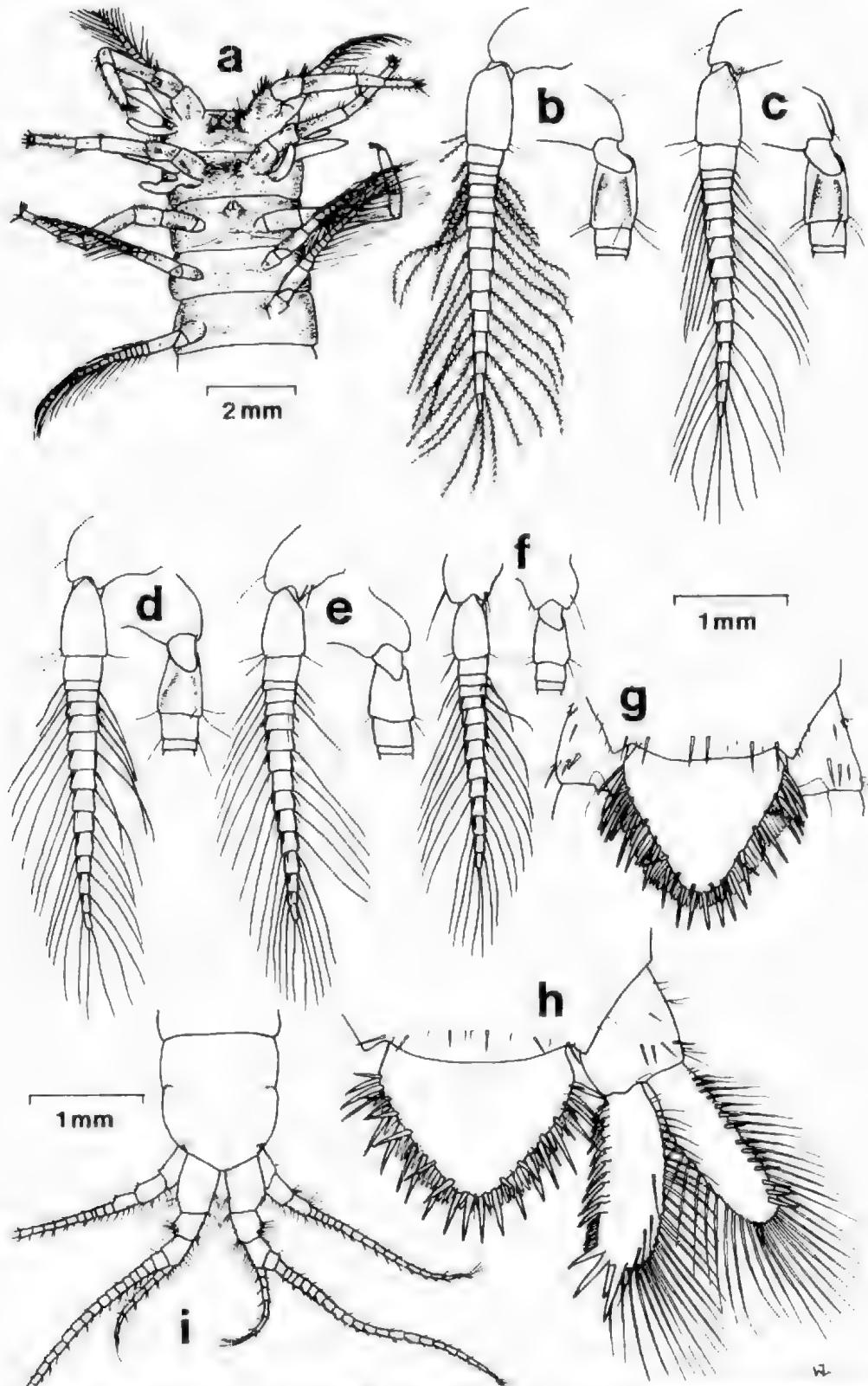
Fig. 5. *Koonunga crenarum* sp. nov. a. spermatheca, ♀ (SAM C3991); b-f Pl 1 5 holotype ♀; g, telson, allotype ♂; h, telson and uropod, holotype ♀; *K. cursor*: i. anterior of ♂ specimen (8.2 mm) from Railway Drain, Bayswater, Vic. (SAM C4016).
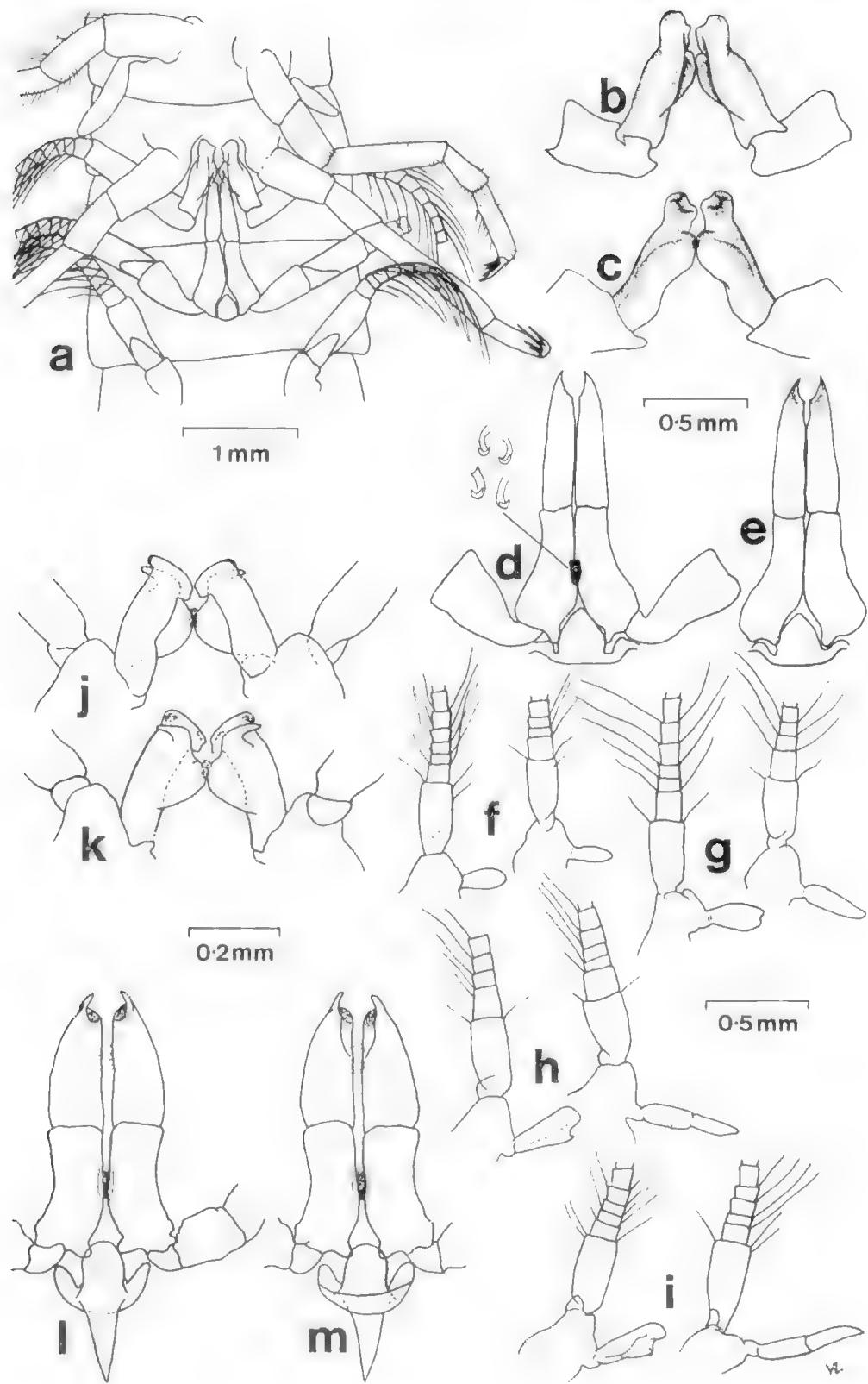
TABLE 1. *Meristic data for* Koonunga crenarum *sp. nov. holotype (H), allotype (A) and paratypes (P). All measurements from dorsal aspect. Unless indicated otherwise the number of segments refer to the flagellum.* "D" *damaged or broken.*

Character	H ♀ C3989	A ♂ C3990	P ♀'s	P ♂'s
Length (mm)				
Head	3.2	2.8	3.0 – 3.7	2.0 – 2.4
Pereon	6.2	4.6	5.5 – 6.7	3.4 – 5.0
Pleon	7.7	6.2	6.7 – 8.3	4.4 – 5.8
Telson	1.2	1.2	1.0 – 1.5	0.7 – 1.1
Total	18.3	14.8	16.5 –20.2	10.5 –14.3
Antennule LHS (RHS)	13.5 (13.6)	9.9D (13.1)	10.9 (11.6)-14.9D (13.7D)	8.4 (8.2)-12 (10.3D)
Antenna LHS (RHS)	8.6 (9.6)	7.5 (7.1D)	7.5 (7.4)-10.5 (10.4)	5.4 (5.1)-7.5 (7.8)
Ratio Pleon/Pereon	1.24	1.35	1.17– 1.25	1.16– 1.32
Breadth (mm)				
Head	2.8	2.3	2.3 – 3.1	1.6 – 2.1
Pereonite 7	3.2	2.4	2.5 – 3.0	1.8 – 2.3
Pleonite 3	3.4	2.5	2.8 – 3.2	2.0 – 2.6
Telson	1.7	1.45	1.5 – 2.0	1.1 – 1.3
Antennule (segments)				
Inner ramus LHS (RHS)	16 (15)	14 (14)	15 (15)-17 (16)	7D (11)-14 (15)
Outer ramus LHS (RHS)	56 (48)	39D (59)	45 (50)-57 (57)	43 (43)-55 (43D)
Antenna (segments)				
LHS (RHS)	35 (35)	27 (33D)	34 (28)-40 (40)	24 (24)-33 (37)
Pereopods (segments/exopodite)				
1 LHS (RHS)	14 (14)	13 (13)	13 (13)-15 (15)	10 (10)-12 (12)
2 LHS (RHS)	15 (15)	D (15)	15 (15)-17 (18)	11 (12)-14 (14)
3 LHS (RHS)	16 (15)	16 (16)	15 (15)-18 (D)	12 (12)
4 LHS (RHS)	15 (15)	15 (D)	15 (15)-17 (18)	12 (11)-14 (12)
5 LHS (RHS)	15 (15)	15 (D)	14 (14)-17 (16)	11 (11)-14 (14)
Pleopods (segments)				
1 LHS (RHS)	15 (15)	15 (15)	15 (15)-16 (16)	11 (11)-14 (13)
2 LHS (RHS)	15 (15)	15 (15)	15 (15)-16 (16)	11 (11)-14 (14)
3 LHS (RHS)	15 (15)	15 (D)	15 (15)-16 (D)	11 (11)-14 (14)
4 LHS (RHS)	15 (15)	15 (D)	15 (14)-16 (D)	11 (11)-13 (14)
5 LHS (RHS)	13 (13)	13 (13)	13 (13)-14 (14)	9 (D) –12 (12)
Uropod spines				
Inner ramus—inner dorsal				
LHS (RHS)	12 (12)	11 (12)	13 (13)	11 (11)-12 (12)
Outer ramus—outer dorsal				
LHS (RHS)	D (14)	18 (17)	15 (15)-17 (17)	13 (13)-18 (17)

59 segments (RHS; LHS broken); inner flagellum of 14 segments (LHS & RHS).

Antenna (Fig. 4d): left with flagellum of 27 segments, right broken but still with 33 segments.

Percopods: similar to holotype but all with four dactyl claws. Pl-6 without coxal lobes.

Pleopods: 1 and 2 with endopodites modified to form complex copulatory styles (petasma). Petasma (Fig. 6a) directed anteriorly against mid-ventral surface between, and posterior to, last pair of pereopods.

Endopodite of Pl 1 (Figs 6b, c) unsegmented, grooved for about middle half of external inner margin to provide sleeve for endopodite of Pl 2; cup-shaped terminally, directed inwards and towards body. Endopodites joined about 2/3 from base by

coupling spines on extension of internal, inner margin.

Endopodite of Pl 2 (Figs 6d, e) of 2 segments of about equal length, each as long as endopodite of Pl 1. Basal segment slightly expanded proximally with coupling spines on small pad near centre of internal, inner margin and with small basal projection on inner proximal corner articulating with sternal process. Distal segment apically pointed, hollowed out on distal, inner margin to form concave depression directed towards body. Sternal process (Figs 6d, e): triangular in shape, slightly longer than wide, slightly less than 1/2 length of basal segment of endopodite of Pl 2, fitting inbetween basal 1/4 of endopodites of Pl 2. Telson (Fig. 5g): slightly more pointed apically than

Fig. 6 *Koonunga crenarum* sp. nov. a. petasma, allotype ♂; b. endopodite Pl 1 ventral view; c. reverse of b; d. endopodite Pl 2; e. reverse of d; f-i. endopodites Pl 1 (LHS) & Pl 2 (RHS) of specimens 7.9, 8.4, 9.3 & 10.1 mm length respectively, ♂ cursor: ♂ 6.6 mm (SAM C4016); j. endopodite Pl 1; k. reverse of j; l. endopodite Pl 2; m. reverse of l.

in type, lateral margins straight or even slightly concave.

Etymology: From Greek mythology, "crenae" being nymphs of springs.

Variation: The paratypes are similar to the type or allotype. Variation in size and other meristic characters is shown in Table 1. Not shown in Table 1 is slight variation in the number of dactyl claws on the pereopods, the number of large terminal spines of the inner ramus of the uropods and the relative lengths of the pereopods and pleopods. The pereopods usually have four dactyl claws but sometimes in the larger specimens P4–7 may have five dactyl claws e.g. holotype and female paratype SAM C3991. The inner ramus of the uropods usually has three large terminal spines but in SAM C3991 and on RHS of the holotype there are four spines. The pereopods and pleopods have not been measured for each specimen and show only slight variations from the holotype. In the male SAM C3992, P2 & 7 are the longest and P4-6 are the shortest, equal in length and slightly shorter

than the Mxp; the pleopods are like those of the holotype.

The non-type material exhibits the same variation. Specimens from various localities have been examined in detail, and cannot be distinguished from those from the type locality.

Some specimens appear to be more slender than others and at first it was thought that two species might be present, however, the relationship between length and breadth shown in Fig. 7 indicates that breadth is a variable character especially in larger specimens. The pleon/percon ratio is also variable, ranging from 0.99 to 1.77 but does not appear to be related to length, breadth or sex of specimens.

Females varied in length from 5.9 to 22.6 mm with a mean length of 13.8 ± 0.5 mm ($\pm 95\%$ c.l.). Males ranged in length from 7.8 to 16.2 mm with a mean length of 10.9 ± 0.5 mm ($\pm 95\%$ c.l.) which is significantly smaller than that of the females ($P < 0.01$). The female sample is larger (176/60 ♀:♂). However, seasonal fluctuations in the proportion of males in the population may account for some
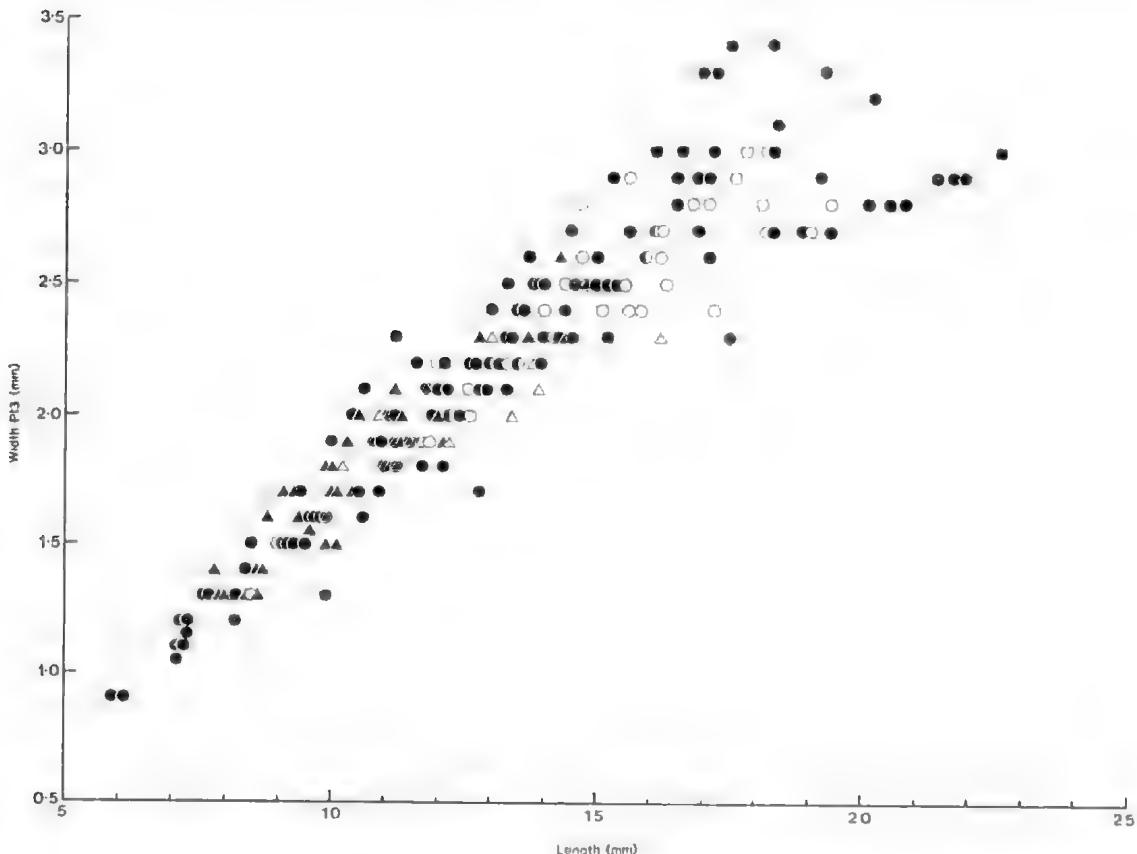

Fig. 7. *Koonunga crenarum* sp. nov. Relationship between length and breadth (pleonite 3). Females closed circles, males closed triangles; open symbols refer to specimens from localities other than the type locality.

of the observed imbalance as 45/128 specimens were males in July, 1984 compared to 0/11 in January, 1981; 2/17 in March, 1981 and 3/28 in March, 1982—all from the type locality.

Development of the petasma and sensory organ of male

A relatively large collection of males from the type locality in July, 1984 (SAM C3996) included a number of very small specimens which exhibited various stages in the development of the petasma and also the sensory organ of the antennule. The development of these sexually dimorphic characters in syncarids has not been reported in the literature.

The endopodites of Pl 1 and Pl 2 develop laterally from the base of the pleopods until they overlap and are fully developed; they are then directed longitudinally forward but are not linked by the coupling spines until the sternal process is also fully developed. The earliest stage observed was at a length of 7.9 mm (Fig. 6f). At this stage the endopodites are only recognisable as single, small, rounded segments and the sternal process is not visible. In the next stage at 8.4 mm (Fig. 6g) the endopodite of Pl 1 is beginning to differentiate but the sternal process has not developed further. At 9.3 mm (Fig. 6h) the endopodite of Pl 1 is beginning to form its characteristic shape; the endopodite of Pl 2 has divided into two segments and the sternal process is recognisable as a small ridge. At 10.1 mm (Fig. 6i) the endopodite of Pl 1 is almost fully developed with coupling spines; the endopodite of Pl 2 is also almost fully developed but lacks the concave depression at the tip and the sternal process has not developed further. A specimen at 9.6 mm had a fully developed petasma and sternal process but the endopodites of Pl 2 were still not linked by coupling spines. Other specimens at about 10 mm exhibited fully developed male sexual characteristics.

The sensory organ on the antennule arises from a depression on the inner margin of the second segment of the outer flagellum (Figs 8a, b) and develops into a pedunculate eye-like organ with the rounded outer surface covered with minute cup-like structures attached to the surface by a short stalk (Fig. 8e). The basal segment of the inner flagellum becomes modified developing a saucer-shaped lobe on the dorsal surface which partly shields the sensory organ (Figs 8d, e). The earliest stage observed was at a length of 8.4 mm (Figs 8a, b). At this stage the sensory organ is only a small protuberance and the basal segment of the inner flagellum is undifferentiated. At 9.3 mm (Fig. 8c) the sensory organ has developed into a ball-shaped structure but the basal segment of the inner flagellum is still unmodified. At 10.1 mm (Fig. 8d) the sensory organ is larger and more pedunculate and the basal segment of the inner flagellum is beginning to differentiate forming a small lobe on the dorsal surface. A specimen at 11.3 mm (Fig. 8e) had an almost fully developed sensory organ and the basal segment of the inner flagellum had become broader and saucer-shaped with a fringe of long setae on the dorsal margin, partly shielding the sensory organ.

Sayce (1908) in his description of *K. cursor* described and illustrated the sensory organ arising from the basal segment of the outer flagellum and a saucer-shaped lobe shielding the sensory organ as arising from the terminal segment of the peduncle. An examination of some specimens of *K. cursor* from Bayswater, Victoria (SAM C4016) demonstrate that these male sexual characters (Fig. 8f) are similar to those of *K. crenarum* sp. nov. and that Sayce (1908) was in error in his determination of these features.

In view of the above it is possible that specimens less than 8 mm in length may be difficult to sex but as only 10 females were this small it would make little difference to the proportion of males/females observed.

TABLE 2. *Distinguishing characters of* Koonunga cursor *and* K. crenarum *sp. nov*

Character	*K. cursor*	*K. crenarum*
Specimen length ♀	rarely exceeds 10 mm	exceeds 20 mm
Antennule length	approx. ½ body length, when attached barely reaches perconite 3.	approx. ¼ body length, when attached reaches past perconite 7.
Head	evenly rounded anteriorly, antero-lateral incision above antenna very small (Fig. 5i)	pointed anteriorly, antero-lateral incision above antenna distinct (Fig. 2)
Eyes	small but present	absent
Petasma (♂)	sternal process with large posterior projection (Figs 6 l, m) Note also distinctive structure of endopodites of Pl 1 & 2 (Figs 6j-m)	sternal process without posterior projection (Figs 6d, e) Note also distinctive structure of endopodites of Pl 1 & 2 (Figs 6b-e)
Dactyl spines	P 1-7 = 3	P 1-3 = 4, P 4-7 = 4-5
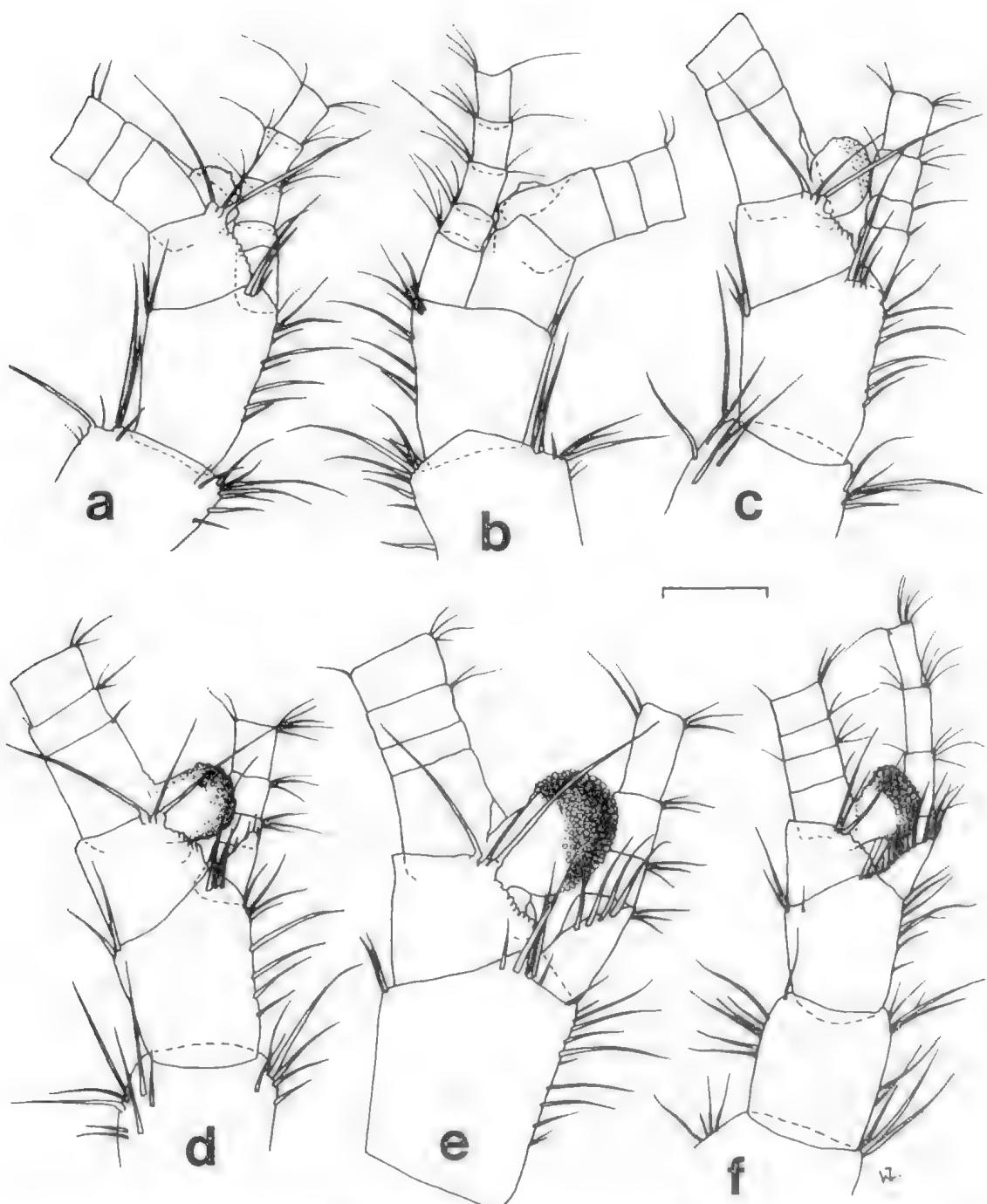
Fig. 8. Sensory organ on antennule (LHS) of—*Koonunga crenarum* sp. nov. (SAM C3996) a & b. dorsal and ventral view, from specimen 8.4 mm; c–e — dorsal view, from specimens 9.3, 10.1 & 11.3 mm length respectively. —*K. cursor* (SAM C4016) f. dorsal view, from specimen 6.6 mm. Scale bar = 0.2 mm.

Discussion

Koonunga crenarum most closely resembles *K. cursor* the only other described congener and can most readily be distinguished from it by the characters given in Table 2. In the lack of eyes it also resembles *Micraspides calmani* Nicholls, 1931, the only other member of the family Koonungidae.

K. crenarum amongst the Koonungidae (including known undescribed species) occupies the most subterranean habitat and is also the largest species. It occurs in depths exceeding 40 m and of particular significance is its occurrence in sinkholes that were only discovered when the roof collapsed e.g. Allendale and The Shaft. All previous records of Australian syncarids are from relatively shallow depths and even the Tasmanian syncarids which inhabit lakes tend to occur near the edges and the deepest record is 8 m, recorded for *Paranaspides lacustris* Smith, 1909 (Williams, W. D. 1974).

As sinkholes and caves are difficult and dangerous environments to explore it is hard to establish the relative abundance of the species with depth although it would seem to be more abundant in the surface waters, especially near vegetation at the edges of the sinkhole or cave. Specimens from the surface and deep water have been compared in detail and appear to be conspecific; pigmentation is similar but deep water specimens are slightly darker. *K. crenarum* does not appear to be a strong swimmer so it is unlikely that regular migrations occur between the surface and the bottom of the sinkholes. It is unlikely that the deep water specimens represent individuals that have become "lost" as many more specimens have been sighted in deep water than have been collected (P. Horne, pers. comm.). *K. crenarum* therefore most probably occurs throughout the depth of sinkholes and caves.

The occurrence of *K. crenarum* in several, sometimes widely separated, sinkholes and caves (Fig. 1) suggests that these environments must have been linked at some time in the past. An underground connection has been a popular theory but is not supported by hydrological evidence (Holmes & Waterhouse 1983) and the animals are too large for interstitial travel. It is most likely that the habitats were once connected by flood waters although they are not located near flats which were subject to annual flooding before drainage (Williams, M. 1974). It is possible that they were isolated before European settlement. Whatever the connection in the past sinkholes and caves are now isolated refuges for a once more widespread fauna.

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TRIGONIOIDIDAE (MOLLUSCA: BIVALVIA) FROM THE CRETACEOUS OF LAKE EYRE NORTH, SOUTH AUSTRALIA

BY P. A. HUTCHINGS & P. S. TURVEY

Summary

Pledgia eyrensis gen. et sp. nov., a species of bivalve mollusc apparently belonging to the Trigonioididae, an important family of non-marine Mollusca in the Cretaceous of Eastern, Central and South-East Asia, is described. The bivalves weather out from unconsolidated fine sand and silt mapped as Winton Formation on the western side of Babbage Peninsula, Lake Eyre North, in the southern part of the Great Artesian Basin. No likely non-marine ancestral forms have been found among the Unionidae and it is possible that ancestors of Pledgia eyrensis may be found in the Trigoniidae.

TRIGONIOIDIDAE (MOLLUSCA: BIVALVIA) FROM THE CRETACEOUS OF LAKE EYRE NORTH, SOUTH AUSTRALIA

by N. H. LUDBROOK*

Summary

LUDBROOK, N. H. (1985) Trigonioididae (Mollusca: Bivalvia) from the Cretaceous of Lake Eyre North, South Australia. *Trans. R. Soc. S. Aust.* 109(3), 77-82, 29 November, 1985.

Pledgia eyrensis gen. et sp. nov., a species of bivalve mollusc apparently belonging to the Trigonioididae, an important family of non-marine Mollusca in the Cretaceous of Eastern, Central and South-East Asia, is described. The bivalves weather out from unconsolidated fine sand and silt mapped as Winton Formation on the western side of Babbage Peninsula, Lake Eyre North, in the southern part of the Great Artesian Basin. No likely non-marine ancestral forms have been found among the Unionidae and it is possible that ancestors of *Pledgia eyrensis* may be found in the Trigoniidae.

KEY WORDS: Mollusca, Bivalvia, Trigonioididae, Cretaceous, Winton Formation, Lake Eyre North, Great Artesian Basin.

Introduction

In 1982 a number of grey-coloured, thick-shelled bivalves collected in July from an outcrop on the western side of Babbage Peninsula, Lake Eyre North, were shown to me by Mr Neville Pledge of the South Australian Museum. Similar material had been collected in 1967 by Dr B. Daily of the University of Adelaide. Thought to be of possible Miocene age, those collected earlier were taken to the National Museum of Victoria for identification. As their preservation and colour were similar to Cretaceous marine fossils from the Lake Eyre region and not to Tertiary molluscs of the area, I considered those shown to me to be non-marine Cretaceous bivalves which I had not previously seen in the Cretaceous of the Great Artesian Basin. The material taken to Victoria was then returned to augment that in the South Australian Museum.

Since the original material was collected, the LAKE EYRE 1:250 000 map sheet has been published (Williams 1975). Outcrops of Winton Formation (Cenomanian) are shown west of the fault on the western side of Babbage Peninsula (Fig. 1).

The molluscs were found weathering out from sandy silt to unconsolidated fine sand mapped as Winton Formation, towards the base of a low bluff 4 m high. There is a possibility, not yet substantiated, that the sandy silt has been reworked from the Winton Formation. The locality was revisited in May 1983 by G. W. Krieg and P. A. Rogers of the Geological Survey of South Australia who made further collections from the site and provided the composite section shown in Fig. 2. The Winton sediments are overlain by a layer of massive crystalline gypsum up to 1.5 m thick in which

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occasional bivalves were found reworked. This is followed by pale olive-grey gypsiferous sand and a compact gypsum crust.

In all, 19 more-or-less complete valves and 274 fragments were collected. Some of the specimens were sent to the Geological Survey of Queensland and the Queensland Museum to see whether similar molluscs had ever been found in the Winton Formation in Queensland, but none were known to have been collected there.

They seem to belong to the family Trigonioididae, an important family of non-marine molluscs in the Cretaceous fauna of Eastern, Central and South-East Asia (Yang 1974), previously not known to occur in the Southern Hemisphere.

The family Trigonioididae and its distribution

The family name Trigonioididae was introduced by Cox (1952) to accommodate the genera *Trigonioides* Kobayashi & Suzuki, 1936 and *Hoffetrigonia* Suzuki, 1940 in the Unionacea rather than in the Trigoniacea; Cox excluded from consideration or did not accept those genera as belonging to the Trigoniidae where they had originally been placed. Later (1955) Cox withdrew the family Trigonioididae, considering *Trigonioides* to be a normal representative of the Unionidae. Kobayashi (1956) restored the Trigonioididae as a valid family which has been generally accepted since then and classified within the Unionacea. Eighty-four species have been described, distributed among ten genera and seven subgenera. A second family Peregrinoconchiidae with seven species was described by Gu, Chen & Lan (*in* Lan 1976), while Martinson (1984) erected the superfamily Trigonioidea to include three families:

Fig. 1. Locality plan with geology of Babbage Peninsula (lake sediments blank)

Trigonioididae, Pseudohyriidae and Sainshandiidae (= Sainschandiidae). Martinson's classification is at present available in abstract only.

The present known distribution of the Trigonioididae in Asian non-marine basins is (Kobayashi 1958): Northern Asia—Lena Basin and eastern Siberia
Eastern Asia—Amur River—Manchuria
Japan and Korea
Mongolia—northwest China.

One species has been described from Colorado USA (MacNeil in Morris 1936).

The Lake Eyre bivalves

The bivalves from Lake Eyre resemble Trigonioididae from eastern Asia chiefly in the structure of the hinge; the sculpture differs in that the radial or chevron patterns of the costae are at best vestigial and the dominant sculpture is finely concentric. The interior of the ventral margin is not crenulated.

According to Kobayashi (1958), the Trigonioididae appeared 'sporadically and explosively in

the maritime basins of eastern Asia at the beginning of the Cretaceous.' The family was considerably augmented in the Lower and Middle Cretaceous by the recognition of important genera such as *Plicatounio* and *Nipponaia* (Ota 1959a, 1959b, 1963). Kobayashi attributes this sudden appearance to some geological event which caused a change in environment, marine bivalves being locked in inland basins during the Sakawa cycle of orogeny. Nevesskaya & Soloviev (1981) show the maximum development of the Trigonioididae to be from the Cenomanian to the Santonian, with minor occurrence in the Campanian and Maastrichtian. Martinson (1984) considers the Trigonioididae to be characteristic of the Early Cretaceous and the Pseudohyriidae and Sainschandiidae of the Late Cretaceous. Reconciliation of these apparent discrepancies will presumably be found in the full text of Martinson's paper when it becomes available.

The age of the Winton Formation at Lake Eyre is considered to be Cenomanian (Ludbrook 1978, Moore 1982, Forbes 1982) or latest Albian to Cenomanian (Moore & Pitt 1982, Krieg 1982).
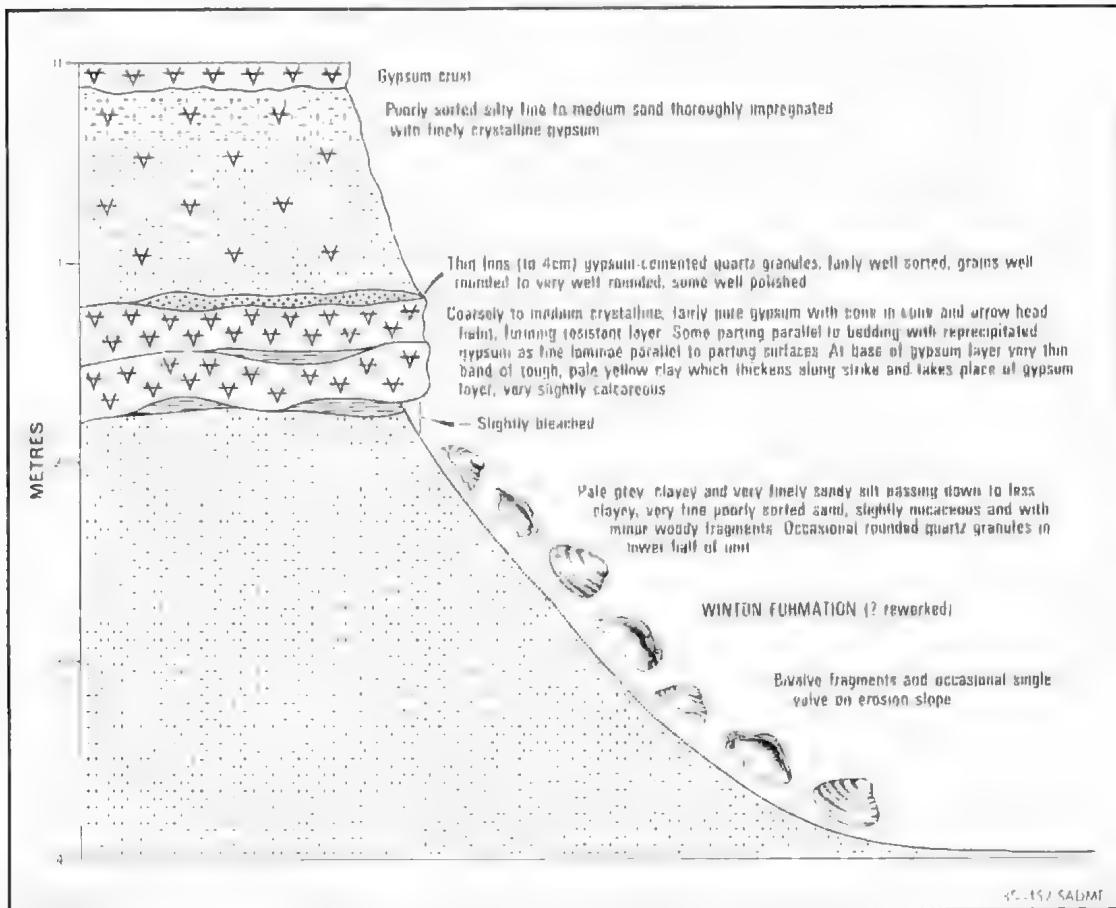
Fig. 2. Composite section of fossil site 6340 RS 4, Lake Eyre North.

Palynological evidence for its Cenomanian age is given by Burger (1982). At this time, following the disruption of Gondwana and extensive marine flooding during the Early Cretaceous, there was a change of regime in the Late Cretaceous and most of the area of the Great Artesian Basin was reduced to a lacustrine remnant (Ludbrook 1978).

Systematic description

Family TRIGONIOIDIDAE Cox, 1952
Genus *PLEDGIA* gen. nov. (fem.)

Shell ovate in shape, elongate-ovate in the juvenile, very thick and heavy, sculpture of concentric growth ridges and concentric lirae. Hinge with anterior teeth relatively short, transversely crenulated, posterior laterals narrow, long, not crenulated.

Pledgia eyrensis gen. et sp. nov.

Material: A total of 19 more-or-less complete specimens and 274 fragments, all from the type locality 6340 RS 4. (Fig.3). South Australian

Museum (SAM): the type series, holotype P23999a, paratypes P23999b–g, fragments P23999h–k, all RVs average length 33, average height 23 mm; paratypes P24000a–h, an ontogenetic series of 8 almost complete LVs average length 30, average height 23 mm; P24639a–p, fragments all approximately length 30, height 20 mm; P24640, about 80 fragments.

Geological Survey of South Australia (GSSA): paratypes 10184a, b, 2 RVs a. length 34, height 22, b. length 30, height 19 mm; 10185 paratype 10185a and 16 fragmentary RVs, largest length 40, height (est.) 32, average of 3, length 33, height 22 m; 10186-10192 104 fragmentary RVs and 61 fragmentary LVs.

Description: Valves of medium size, transversely subovate becoming subovate in adult specimens, narrowly rounded anteriorly, slightly produced posteriorly, anterior-dorsal margin well rounded; umbo located at about the anterior one-quarter, moderately high, prosogyrate; shell very thick,
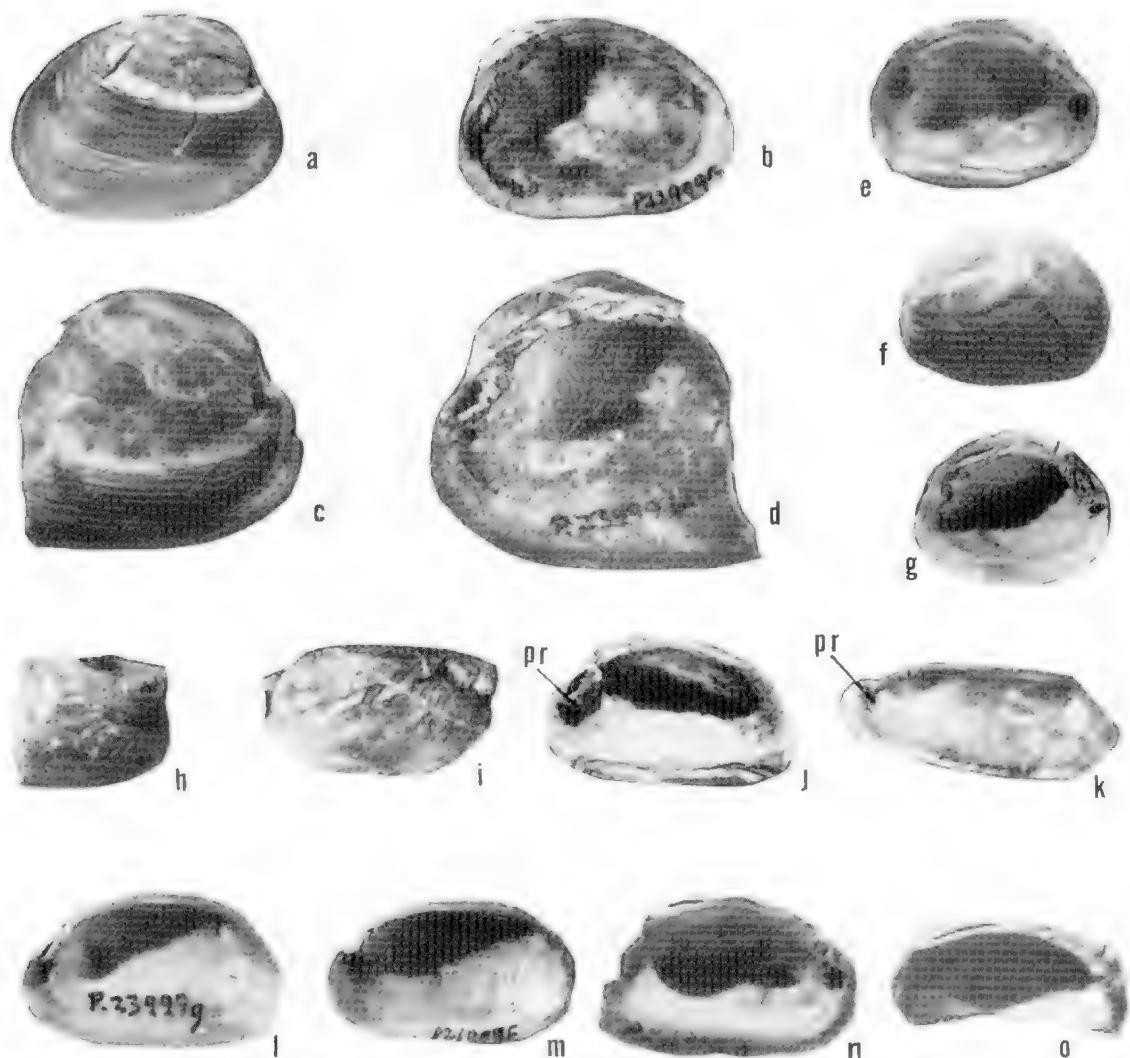
Fig. 3. *Pledgia eyrensis* Ludbrook gen. et sp. nov. a,b. Holotype SAM P23999a RV a. exterior, b. interior; c,d. Paratype SAM P23999b RV large specimen (incomplete) c. exterior showing thick shell with imbricating lamellae, d. interior, worn, with crenulated 3b and deep pit; e,f. Paratype SAM P24000g LV immature specimen e. interior showing deep muscle scars, hinge not fully developed, f. exterior showing radial ridging on both the anterior and posterior slopes; g. Paratype SAM P24000h LV rounded form; h. Paratype SAM P23999h LV fragment showing thick posterior area with radial sculpture; i. Paratype GSSA 10192a LV with differentiated posterior area; j. Paratype GSSA 10184a RV, elongate-oval form with pedal retractor scar just visible under hinge; k. Paratype SAM P23999f, tilted to show pedal retractor; l. Paratype SAM P23999g RV immature specimen, elongate-oval form with anterior cardinal tooth not fully developed; m. Paratype SAM P23999f RV immature specimen, elongate-oval form; n. Paratype SAM P24000b LV immature specimen with well developed posterior laterals, partly developed grooved cardinal, pedal retractor scar visible; o. Paratype GSSA 10185a LV with strong posterior lateral. All figures natural size.

consisting presumably of an outer organic layer or periostracum which is not preserved, an outer very thick (up to 5 mm) calcareous layer composed of successive imbricating lamellae, turned upwards at the ventral margin, which exfoliate very easily leaving the inner layer exposed, and a crystalline inner layer formed of very thin, smooth laminae (see Morton 1967 Fig. 6B) not thickening at the ventral margin. Sculpture on the flank consisting of concentric growth ridges with microscopic concentric lirae between them; faint vestigial radial riblets visible particularly in the anterior part of the flank, a small, thick, posterior area differentiated by having thick radial sculpture. Both the outer and

inner layers are composed of calcite, determined by X-ray diffractometer at the Australian Mineral Development Laboratories (AMDEL Report G584/85). No aragonite was detected. Interior smooth, hinge arcuate with a dental formula of

RV	5	3		PI	PIII
LV		2		PII	PIV

5 is not always present and is crenulated or grooved only in adult specimens, 3 is strong and high, of moderate length and in adult specimens crenulated on both sides with a pit for the reception of 2 in the left valve. PI and PIII are long and narrow, extending the length of the dorsal margin, PII and PIV are fairly long and smooth. The dental formula is somewhat similar to that of *Trigonioides (Wakinoa)* Ota, 1963 as illustrated by Yang (1983). Muscle scars deep, anterior adductor scar close to the anterior margin and to the anterior end of the hinge with a small deep pedal retractor pit above it just under the hinge; posterior adductor scar larger, not so deep, more or less roundly quadrate, pallial line entire, area within the pallial line clearly defined, ventral margin smooth, slightly bevelled but not crenulated

Distribution: Known only from the type locality 6340 RS 4, Babbage Peninsula, Lake Eyre North; Winton Formation, Cenomanian.

Nomenclature: The generic name is to honour Mr Neville Pledge of the South Australian Museum, who collected many of the specimens and first brought them to my notice.

Discussion: The family Trigonioididae was based on the species *Trigonioides kodairai* now reported from many localities from the USSR to Japan (Yang 1974). The morphology, ontogenetic variation and classification of this and related genera and subgenera have been extensively studied by Martinson (1965) and by Yang (1974, 1976, 1978, 1979, 1983).

Pledgia eyrensis seems to have appeared suddenly in the Cenomanian in Australia, but, unlike the Trigonioididae of Eastern Asia as described by Kobayashi (1958), it is not known to have appeared "sporadically and explosively." No likely non-marine ancestral forms have been found among the Unionidae and there appears to be no close relationship between *Pledgia eyrensis* and the Triassic non-marine unionids (Ludbrook 1961) of the Leigh Creek Coal Basin. Immature forms bear only very slight resemblance in sculpture to the Neocomian *Protovirgus coatsi* Ludbrook. 1961, of which the hinge is not known. In shape, sculpture and thickness of shell the adult oval form seems to be most nearly related to the undiagnosed "Trigoniid gen. et sp." of Skwarko (1963 pl. 6, fig. 5) from the Early Cretaceous Wallumbilla Formation south-southwest of Roma, Queensland. This trigoniid is known only from the single specimen figured by Skwarko, which is embedded in hard matrix so that the interior is completely obscured. It does suggest, however, that ancestors of *Pledgia eyrensis* are most likely to be found in the Trigoniidae.

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LARVAE AND PUPAE OF LECTRIDES VARIANS MOSELY AND LEPTORUSSA DARLINGTONI (BANKS), (TRICHOPTERA: LEPTOCERIDAE)

BY J. E. JACKSON

Summary

Final instar larvae and pupae of two species of Leptoceridae, Lectrides varians Mosely and Leptorussa darlingtoni (Banks) are described and figured.

LARVAE AND PUPAE OF *LECTRIDES VARIANS* MOSELY AND *LEPTORUSSA DARLINGTONI* (BANKS), (TRICHOPTERA: LEPTOCERIDAE)

by J. E. JACKSON*

Summary

JACKSON, J. E. (1985) Larvae and pupae of *Lectrides varians* Mosely and *Leptorussa darlingtoni* (Banks), (Trichoptera: Leptoceridae). *Trans. R. Soc. S. Aust.* **109**(3), 83-95, 29 November, 1985.

Final instar larvae and pupae of two species of Leptoceridae, *Lectrides varians* Mosely and *Leptorussa darlingtoni* (Banks), are described and figured.

KEY WORDS: Trichoptera, Leptoceridae, larvae, pupae.

Introduction

The taxonomy of the immatures of Australian Trichoptera is in an early stage of development compared with that of the northern hemisphere fauna, for which keys of larvae to genera and species have been developed (Hickin 1967, Lepneva 1964, Wiggins 1977). Identification of Australian larvae to family is possible using the key of Williams (1980) as revised by Drecktrah (1984), and a key to some free-living and net-spinning genera has been developed by Cartwright & Dean (1982). Few detailed descriptions of Australian larvae are available (examples are Riek (1968), Neboiss (1977b, 1979), and Drecktrah (1984)), and for many species the larvae are not known. No immatures of Australian Leptoceridae are adequately described, despite their dominance in the Australian fauna (Riek 1970).

The leptocerid genus *Leptorussa* Mosely is monotypic: *L. russata* Mosely is considered by Neboiss (1977a) to be conspecific with *L. darlingtoni*. The species is recorded from Queensland, New South Wales, Victoria, South Australia and Tasmania (Neboiss 1983); adults of both sexes are described by Mosely & Kimmins (1953) and Neboiss (1977a). *Lectrides* Mosely includes *L. varians* and the recently discovered *L. parilis* Neboiss, the larva of which is unknown; *L. varians* is recorded from South-east Queensland, Victoria and Tasmania (Neboiss 1983). Taxonomic descriptions of the previously undescribed final instar larvae and pupae of *Lectrides varians* Mosely and *Leptorussa darlingtoni* (Banks) were undertaken prior to a comparative study of the two species[1].

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Methods

Identification of *Lectrides varians* and *Leptorussa darlingtoni* was confirmed by rearing larvae and pupae to adults.

Descriptions of final instar larvae are based on preserved specimens collected from a site near Heathfield, S. Aust., (139°39'E, 35°01'S); pupal descriptions are based on pupae reared from larvae in the laboratory, a few collected specimens, and pupal exuviae. Whole specimens were prepared for microscopic examination by masceration of soft parts in hot KOH (5%) for 10-15 minutes, rinsing in glacial acetic acid, and clearing in clove oil. Specimens were then dissected and prepared as temporary mounts in clove oil, or permanent preparations in Depex. Drawings were made from slides with the aid of a drawing tube on a Wild M20 compound microscope and a camera lucida on a Wild M3 stereomicroscope. Head capsule width of larvae was measured to the nearest 0.01 mm, at the level of the eyes, using an ocular micrometer. Morphological terminology of larvae follows that of Wiggins (1977).

Specimens are deposited in the Museum of Victoria, Melbourne.

Lectrides varians Mosely

Material examined: 25 larvae, from near Heathfield, S. Aust., April 1984, 9 pupae from Heathfield, April 1984, and laboratory reared

Final instar larva

Case (Figs 1, 2). Constructed from roughly quadrate leaf fragments, overlapping in a dorsal and a ventral row; anteriorly, dorsal fragment projects further forward than ventral fragment, forming a hood; filaments of plant material fill between dorsal and ventral rows, and around the anterior opening.

Larva (Figs 3-19). Body length 11-13 mm; head capsule width 0.78-0.81 mm, length 1-1.13 mm. Sclerotized parts golden brown, with distinct paler
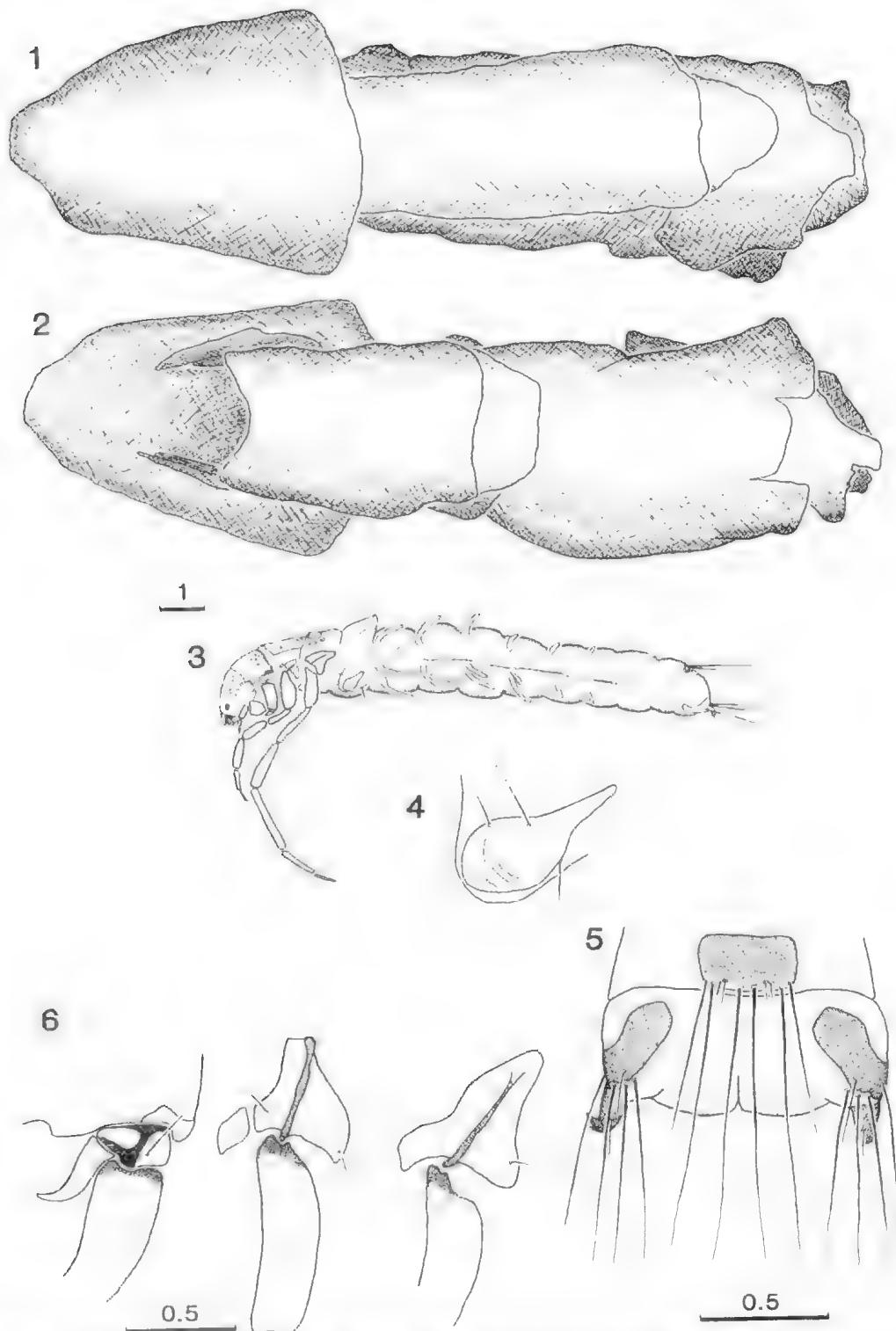
Figs 1–6. *Leetrides varians* final instar larva: 1, 2, case, dorsal and ventral views; 3, larva, lateral view (most setae not shown); 4, left lateral hump, enlarged; 5, abdominal segment IX and anal legs, dorsal view; 6, thoracic pleurites. All scale lines in mm.
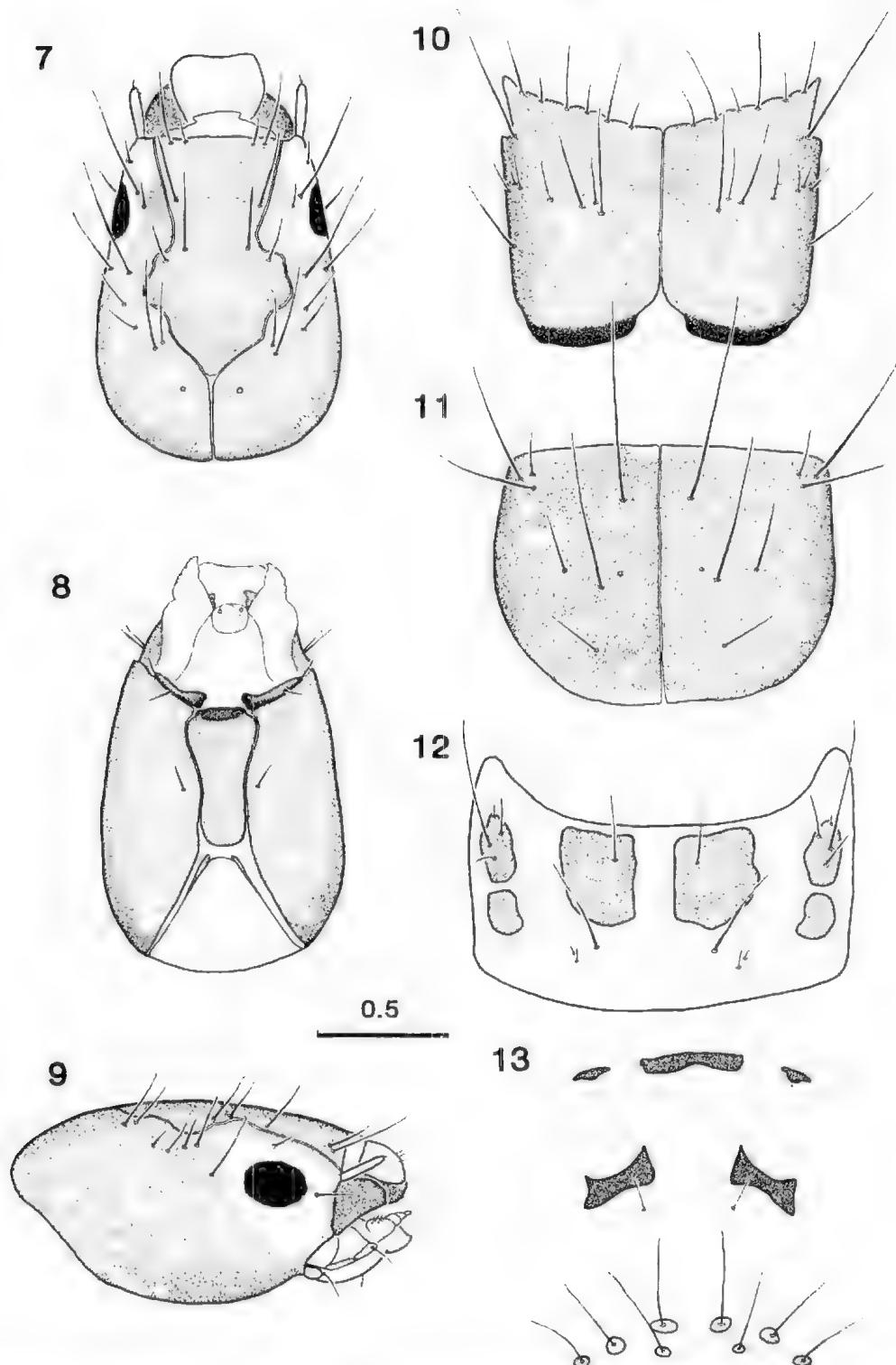
Figs 7–13. *Lectrides varians* final instar larva: 7–9, head, dorsal, ventral and lateral views; 10–12, pro-, meso- and metanota, dorsal view; 13, thoracic sternites. All scale lines in mm.

markings on head and thorax, dark bands on legs. Head (Figs 7–9) with pale spots on parietals, occipital margins and posterior half of genae; ovate in dorsal view, width about 2/3 length. Antennae about length of right mandible, short seta apically. Frontoclypeus strongly constricted medially, expanded posteriorly to slightly greater width than at anterior margin; 2 shallow concavities on posterolateral margins; the resulting irregularities emphasized by adjacent pale spots on parietals. Eyes situated dorsolaterally, just anterior to frontoclypeal constriction, surrounded by pale area.

Labrum (Fig. 15) subovate, anterior margin with shallow indentation, dense fringe of short hair in indentation, ventral brushes of long hair anterolaterally; median paired anterior setae short, pale, in front of three pairs of setae in a transverse row. Mandibles (Fig. 16) with rounded teeth distally on cutting edges, six on left, five on right; left mandible slightly longer than right, inner surface deeply excavated, with two brushes; right mandible only slightly excavated, without brushes. Maxillo-labium (Fig. 14): cardo digitiform with proximal end broadly truncated, bearing one medial and one distal seta; stipes incised medially on inner edge, a lateral and shorter medial seta on distal margin; maxillary palp four segmented, galea lobate, with three finger-like sensillae apically; submental sclerites absent, two long submental setae present; labial palps conspicuous, cylindrical. Ventral apotome (Fig. 8) oblong, about 1/2 length of parietals, width about 1/3 length, broadest anteriorly, tapered to almost 1/2 width posteriorly.

Pronotum (Fig. 10). Anterolateral angles projected forward, acute, slightly upturned; anterior margin concave, shallowly crenate with six pairs of marginal setae arising in constrictions; transverse row of setae just anterior to middle of notum; posterior margin heavily sclerotized. Mesonotum (Fig. 11) rounded posterolaterally, setae sparse, three setae grouped in each anterolateral angle. Metanotum (Fig. 12) only partially sclerotized; 2 subquadrate sclerites anteromedially and smaller paired sclerites laterally; a single seta in each medial sclerite, three in anterolateral sclerites, one long and two very short setae posterior to each medial sclerite. Prosternum (Fig. 13) with dark brown sclerotized bar on posterior margin, smaller bar on each side; pair of mesosternal sclerites; metasternum with 8–10 setae in two curved transverse rows, most arising from small round sclerites.

Legs (Figs 17–19). Forelegs (Fig. 17) short, segments decreasing in size distally, coxa and femur subtriangular, coxa with band of setae offset from posterolateral margin. Fore-trochantin horn-shaped, upturned apically, one seta on ventral margin. Trochanter with short spur on distal angle, distally a ventral brush of short pale setae. Femur length about 2× width; row of short pale setae ventrally. Tibia cylindrical; anteriorly three dark spurs; ventrally four; row of short pale setae ventrally. Tarsus with three spurs ventrally; tarsal claw stout, curved, slightly shorter than tarsus, basal spur almost length of claw. Midleg (Fig. 18) about 1½ × length of foreleg, segments subequal. Trochanter with ventral brush. Femur bears seven dark spurs ventrally and comb of minute spines basally on distal segment. Tibia with seven spurs on anterior face, five ventrally. Tarsus with four spurs, row of pale setae distally; tarsal claw stout, slightly curved, basal spur short. Hindleg (Fig. 19) about 2× length of midleg. Trochanter with row of seven small dark spurs on distal 1/3, femur with seven dark spurs ventrally, two small spurs near division. Tibia almost 2× length of other segments, divided subequally, basal segment with five spurs, distal with eight. Tarsus with six dark spurs ventrally; tarsal claw robust, basal spur short.

Abdomen (Fig. 3) dorsoventrally flattened; lateral fringe dark, on segment VIII reduced to only a few hairs; segment VIII with lateral row of spicules on anterior half; hairs on segments II–IX; II, four dorsolateral; III–VII, two ventrolateral; VIII, six dorsal two ventrolateral; IX, two dorsolateral. Lateral humps (Fig. 4) each with clavate sclerite and three setae; dorsal hump conical, two pairs of fine setae. Tergite IX (Fig. 5) rectangular; three pairs of marginal setae posteriorly, each outer one shorter than others, two pairs of very short setae offset from margin. Lateral sclerites of anal legs uniformly brown. Gills single, finger-like, in following positions: segment I, posterior dorsal; segments II–VI, anterior dorsal, lateral and ventral; segment VII, anterior dorsal and ventral (presence variable).

Pupa (Figs 20–34). Length 11.5–12.5 mm. Legs without apical hooks or claws, fore- and midlegs with dense hair fringes. Antennal bases each with seven erect black setae. Labrum (Fig. 23) with lateral margins straight, converging anteriorly; anterior margin rounded; five pairs of setae anterolaterally. Mandibles (Figs 28–31) broad-based, slender apically; inner margin roughly serrate, with or without a well developed projection; paired setae on outer surface near base. Terminalia of abdomen (Figs 32–34) with two small dorsal processes, each bearing four strong anterolaterally directed setae; male (Fig. 33) with pair of fleshy clasper-shaped ventral protuberances with bulbous process between bases; female (Fig. 34) with ventral hump. Anal processes rod-like, longer than 9th abdominal segment, apices curved dorsad and pointed, 2–3 short setae arising from inner margin subapically.
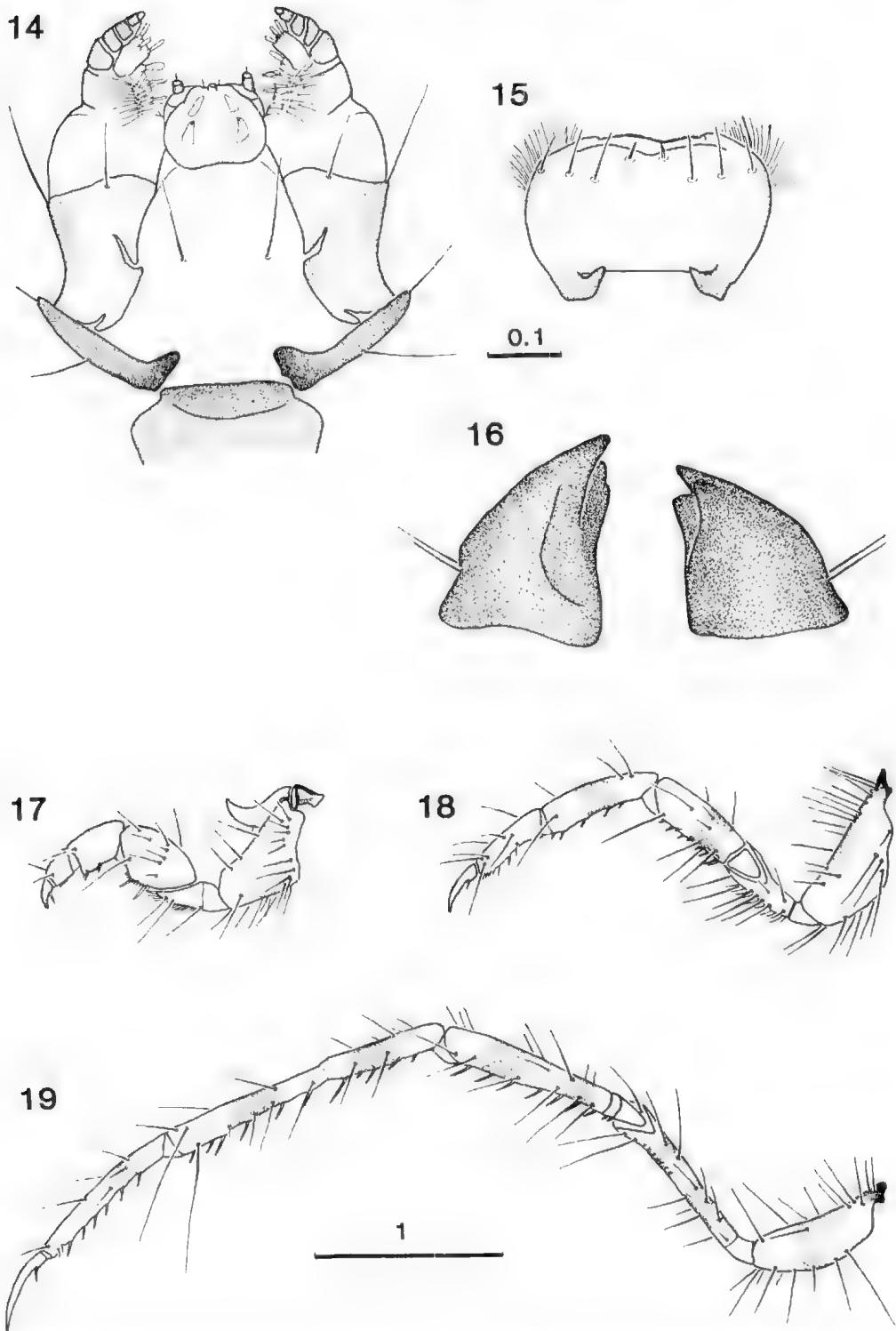
Figs 14-19. *Lectrides varians* final instar larva: 14, maxillo-labium, showing association with head capsule, ventral view; 15, labrum, dorsal; 16, mandibles, dorsal; 17-19, fore-, mid- and hindlegs, left. All scale lines in mm.
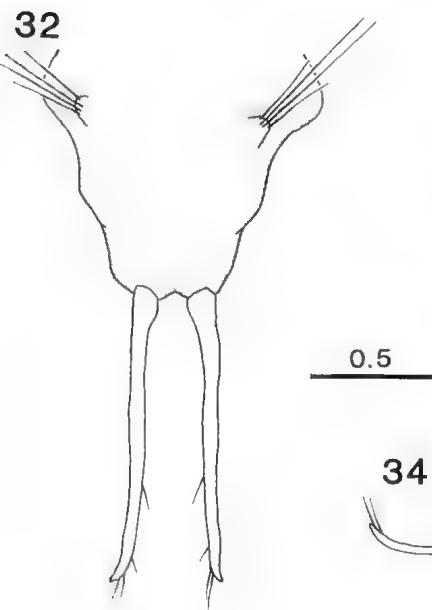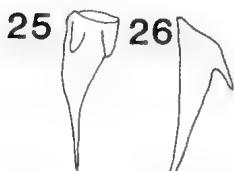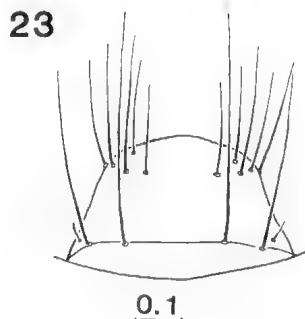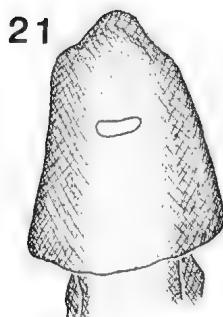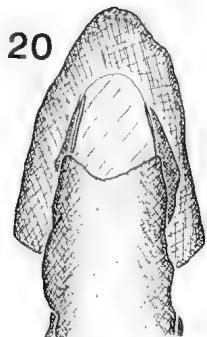
a 4th about 2/3 from basal end. Posterior angles of abdominal segment I bear transverse oblong plates with thickened ridges (Fig. 24); segments III–VI bear elongate anterior hookplates (Figs 25, 26) with 2–3 prominent posteriorly-directed hooks; segment V with rectangular posterior hookplates (Fig. 27) bearing three anteriorly-directed hooks. Segments II–VII with paired T-shaped sclerites dorsally and ventrally, proximal bar of T reduced in ventral sclerites.

Pupal Case (Figs 20–22). Larval case modified by closure anteriorly with oblique silk membrane, with which attached to substrate; transverse vent in anterior dorsal plate, through which larval sclerites ejected; posterior closure perpendicular leaf fragment; orientation of pupa reverse of larval orientation.

Leptorussa darlingtoni (Banks)

Material examined: 20 larvae, from near Heathfield, S. Aust., April, May 1984, six pupae laboratory reared.

Final instar larva

Case (Fig. 35). Length 8–12 mm, constructed of sandgrains, cylindrical, tapering posteriorly, slightly curved; anterior margin usually straight or with small dorsal process; posterior membrane absent.

Larva (Figs 36–55). Body length 6–8 mm; head capsule width 0.54 mm, length 0.73–0.77 mm. Head and thorax dark brown; distinct pale markings on head, usually pale cross on frontoclypeus, thorax mottled. Legs golden-brown with indistinct darker bands.

Head (Figs 43–45) ovate in dorsal view, width about 2/3 length. Antennae about length of right mandible, short seta apically. Frontoclypeus sub-pandurate. Eyes situated dorsolaterally, just anterior to fronto-clypeal constriction, surrounded by pale area.

Labrum (Fig. 52) subovate, anterior margin with four setae in shallow indentation, one long seta arising from each anterolateral margin, medially three pairs of setae in transverse row. Mandibles (Figs 54, 55) with prominent teeth distally, six on left, five on right; left slightly longer than right, inner surface deeply excavated and bearing two small brushes; right only slightly excavated, without brushes. Maxillo-labium (Fig. 53): cardo blunt proximally, attenuated laterally, bears 1 medial and one distal seta; stipes with one lateral and one

shorter medial seta on distal margin; maxillary palps three segmented, galea lobate, a single sensilla apically; submental sclerites quadrate, two long submental setae; palpigers Z-shaped, very narrow. Ventral apotome (Fig. 44) rectangular, width about 2/3 length, slightly narrower anteriorly.

Pronotum (Fig. 46) rectangular; anterior margin pale, with 6–7 pairs of regularly spaced setae; lateral margins (Fig. 40) with row of about seven setae; posterior margin heavily sclerotized. Mesonotum (Fig. 46) rounded posterolaterally, four pairs of scattered setae dorsally, about seven setae grouped in each anterolateral angle. Metanotum (Fig. 46) mostly membranous; medially two small irregular sclerites, bearing one short seta on anteroproximal angle, laterally three long setae. Prosternal sclerite absent, two small dark mesosternites (Figs 47, 48), metasternum with 4–5 pairs of setae.

Legs (Figs 49–51). Anterior face of coxae much more densely setose than posterior face, other segments with few setae. Foreleg (Fig. 49) short and robust. Fore-trochantin (Fig. 40) truncated distally, anterodorsal angle produced forward slightly, two setae on anterior margin. Trochanter with two pale spurs near distal angle, brush of short pale setae distally. Femur width about 2/3 length, comb of small pale spurs ventrally. Tibia dilated distally, four spurs on ventral margin. Tarsal diameter about 1/2 that of tibia at joint, six spurs ventrally; tarsal claw as long as tarsus, basal spur about 1/2 length. Midleg (Fig. 50) almost 2× length of foreleg, less robust, segments (except for short trochanter) decreasing in size distally. Distal segment of trochanter with ventral brush of pale setae. Femur bears comb of small pale spurs near base of distal segment. Tibia curved basally, spur arising 2/3 from basal end. Tarsus with ventral row of small pale spurs on distal 2/3. Hind leg (Fig. 51) slender, about 2× length of midleg, segments subequal. Trochanter with comb of small pale spurs on distal 1/2 of posterior face. Femur with similar comb at base of distal segment. Tibia bears one spur near distal end. Tarsal spur arises medially; tarsal claw slender, curved slightly to a fine point, length about 2/3 length of tarsus, basal spur about 1/4 of length.

Abdomen (Fig. 36) creamy white, slightly dorso-ventrally flattened; lateral fringe short, fine; segment VIII with complete lateral row of spicules, lateral fringe absent; segments VI–VIII with dorsal hairs: VI-2, VII-4, VIII-6. Lateral humps of segment I (Fig. 37) each with a sclerotized bar,

Figs 20–34. *Lectrides varians* pupa. 20–22, case, anterior end in ventral and dorsal views, posterior closure; 23, labrum and anteclypeus, dorsal; 24, right sclerotized plate of abdominal segment I; 25–27, right abdominal hookplates, anterior hookplate dorsal and lateral view, posterior hookplate dorsal view; 28–31, mandibles, left, without inner projection (28–29) and with inner projection (30–31); 32–34, terminalia of abdomen, dorsal, male ventral, and female lateral views. All scale lines in mm.
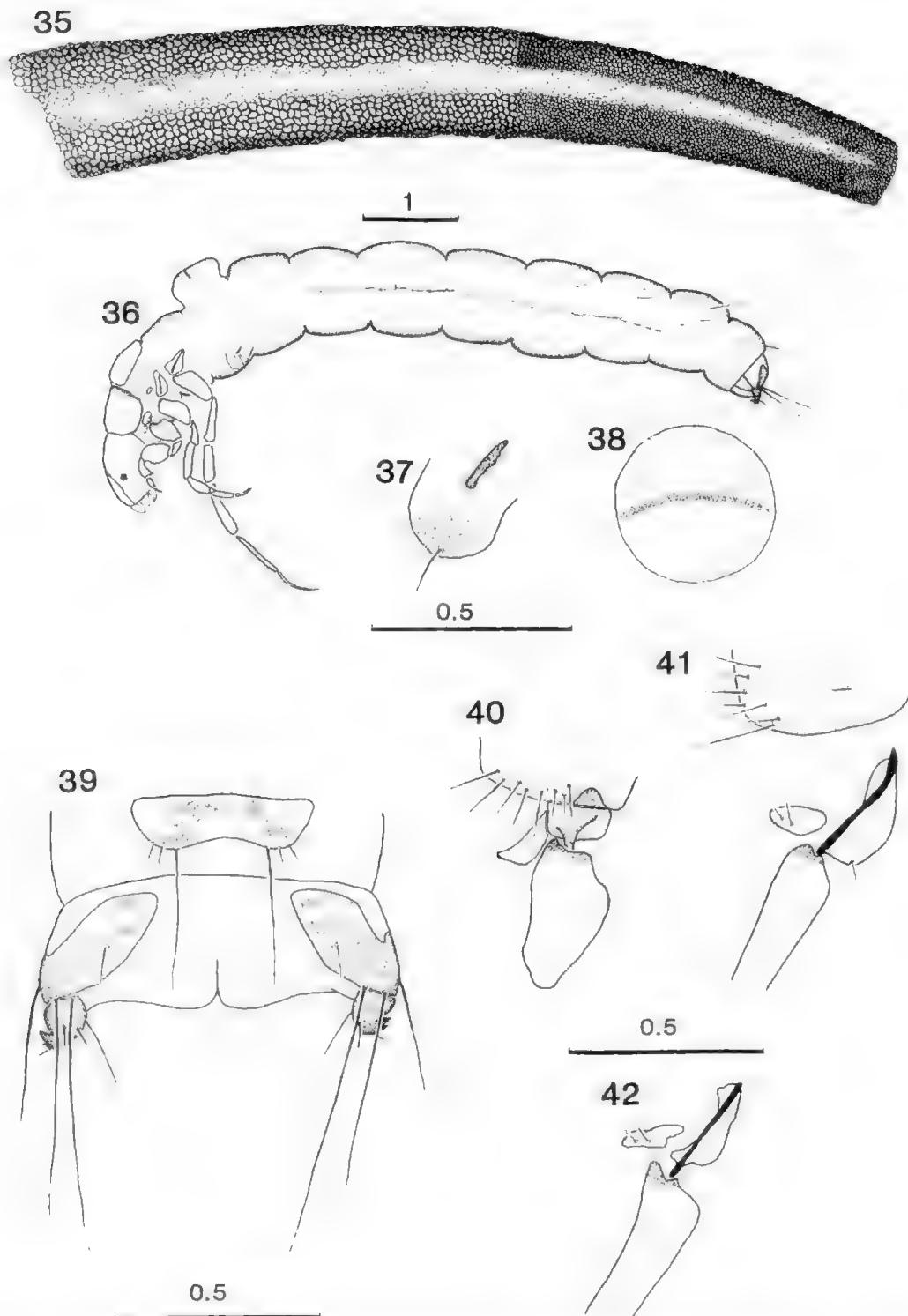
Figs 35–42. *Leptorussa darlingtoni* final instar larva: 35, case, lateral view; 36, larva, lateral view (gills not shown, most setae not shown); 37, left lateral hump, enlarged; 38, dorsal hump, dorsal view; 39, abdominal segment IX and anal legs, dorsal view; 40–42, pro-, meso- and metapleurites. All scale lines in mm.
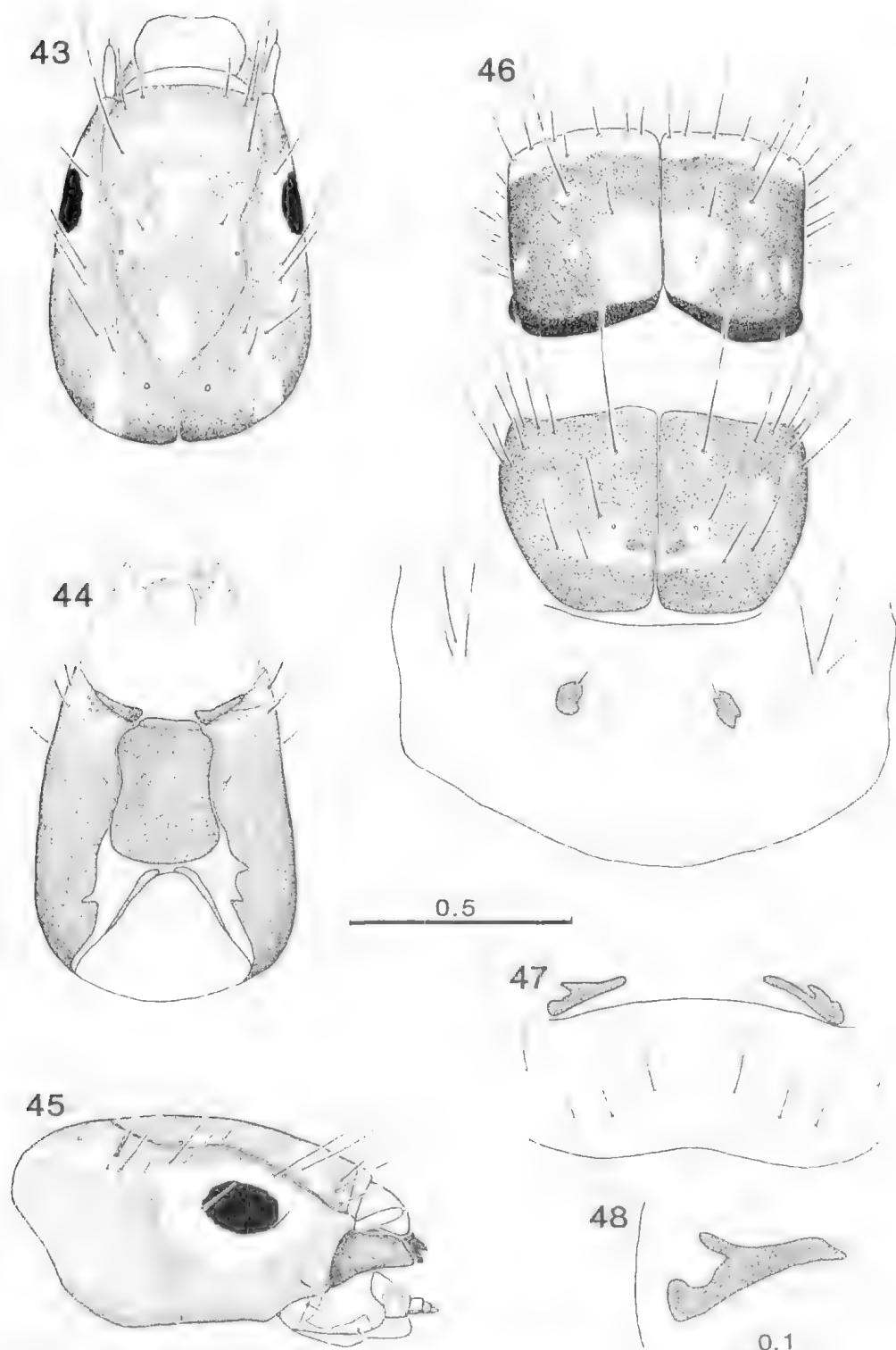
Figs 43–48. *Leptorussa darlingtoni* final instar larva: 43–45, head, dorsal, ventral and lateral views; 46, thoracic nota, dorsal view; 47–48, meso- and metasterna, enlarged mesosternite. All scale lines in mm.
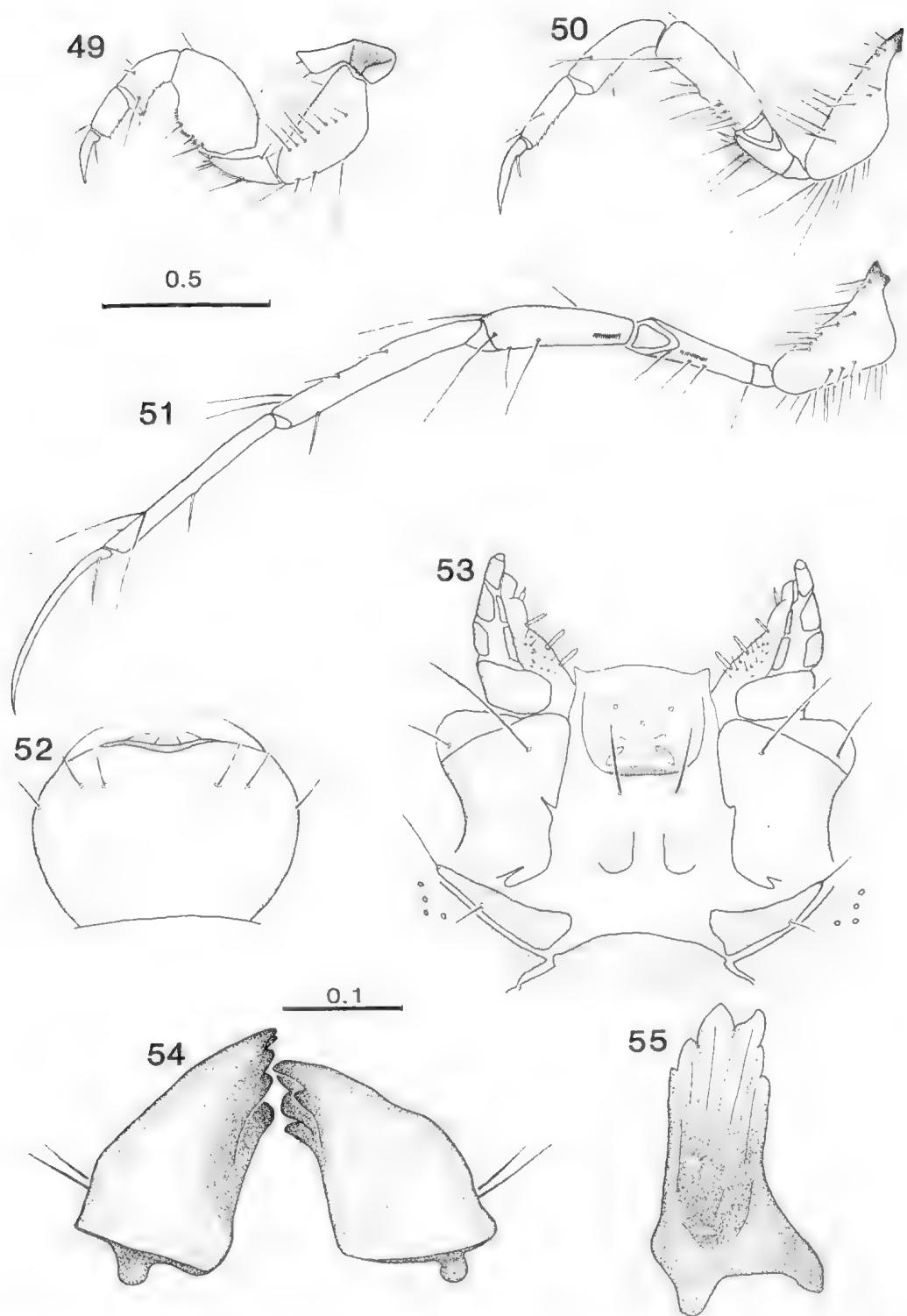
Figs 49-55. *Leptorussa darlingtoni* final instar larva: 49-51,fore-, mid- and hindlegs, left; 52, labrum, dorsal view; 53, maxillo-labium, showing association with head capsule, ventral view; 53, labrum, dorsal view; 54-55, mandible, interior face. All scale lines in mm.

TABLE 1. *Arrangement of the gills of* L. darlingtoni.

Segment	Dorsal	Lateral	Ventral
I	p 3br	—	p 2br
II	a 3br	a 3br	a 3br
III	a 3br	a 1br	a 3br
IV	a 3br	—	a 3br
V	a 2br	—	a 1/2br
VI	a 1br	—	a 1/2br, present/absent
VII	a 1/2br	—	1 1br, present/absent

p=posterior, a=anterior, br=branched.

spinulose distally, a single medial seta; dorsal hump (Fig. 38) flat, with medial transverse sclerotized band, roughened with minute spicules anteriorly. Tergite IX (Fig. 39) width greater than 3× length, mostly unpigmented, with irregular dark spots; three setae laterally on posterior margin, medial setae much longer than others. Lateral sclerites of anal legs mostly unpigmented in anterior 1/2, few irregular spots. Anal claw with one small dorsal accessory hook. Gills filamentous, branched, arrangement as in Table 1.

Pupa (Figs 56–66). Length approximately 8 mm. Legs without apical hooks; fore- and midlegs with dense hair fringes, those of foreleg less dense. Antennae long, coiled several times around end of abdomen, antennal bases without setae. Labrum (Fig. 61) semicircular, two short setae anteriorly, five long setae on each lateral margin. Mandibles (Fig. 61) pincer-shaped, distal 1/2 of inner margin serrate, two setae on outer surface near base. Terminalia of abdomen (Figs 63–66) with two small dorsal processes, each bearing four strong antero-laterally directed setae; male pupa (Fig. 63) with three bulbous ventral protuberances. Anal processes (Fig. 66) rod-like, longer than 9th abdominal segment, apices curved dorsad and pointed; sparsely

covered with short pale hairs, two long setae arising from inner margins subapically, one short seta basal to these and fourth about 1/5 from basal end. Abdominal segment I bears pair of transverse oblong plates with thickened ridges; segments III–VI bear elongate anterior hookplates (Fig. 59) with 2–3 prominent posteriorly-directed hooks; segment V with rectangular posterior hookplates (Fig. 60) bearing 2–3 anteriorly-directed hooks. Segment II–VII with paired T-shaped sclerites dorsally and ventrally, proximal bar of T reduced in ventral sclerites.

Pupal Case (Figs 56–58). Larval case modified by closure anteriorly with plate of sand grains bound with silk just in from rim (Fig. 57); posteriorly thick silk membrane, intact until larval ecdysis when trefoil-shaped vent is formed (Fig. 58); pupa in larval orientation, pharate adult escapes by opening anterior plate like trapdoor. Case attached to substrate with stalked disks (Fig. 56) anteriorly, or anteriorly and posteriorly.

Acknowledgments

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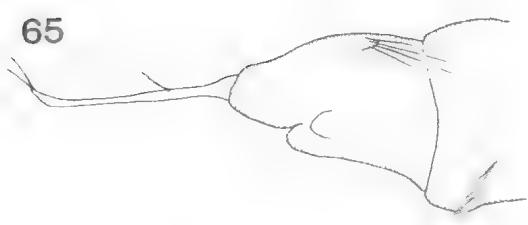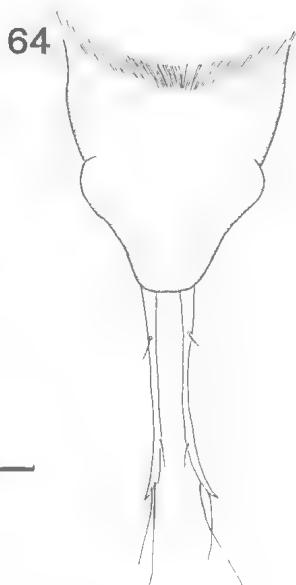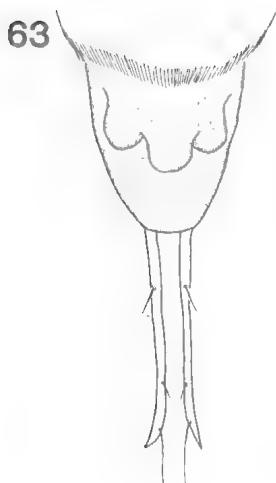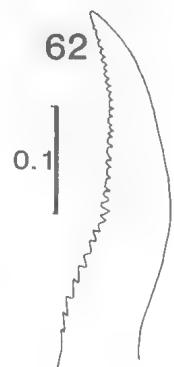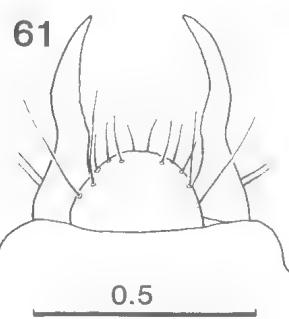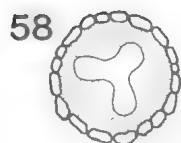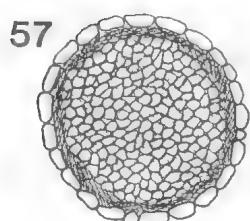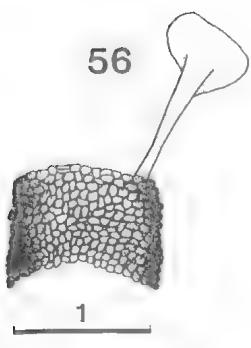
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Figs 56–66. *Leptorussa darlingtoni* pupa: 56–58, case, stalked-disk attachment, anterior and posterior closures; 59–60, anterior and posterior hookplates; 61, labrum and mandibles, dorsal view; 62, mandible, enlarged; 63–66, terminalia of abdomen, male ventral, female ventral, male lateral views, enlarged anal process. All scale lines in mm.

FOUR NEW SPECIES OF HYDROPTILIDAE (TRICHOPTERA) FROM THE ALLIGATORS RIVERS REGION, NORTHERN TERRITORY

BY A. WELLS

Summary

Four new species of micro-caddis fly (Hydroptilidae) from the Alligator Rivers region, Northern Territory, are described in the genera Hellyethira, Tricholeiochiton, Oxyethira and Orthotrichia; notes are given on their possible relationships. Collecting data for three species suggest that these show strong seasonality, with two species emerging almost exclusively in the dry season (July), and one in the wet (March).

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Four new species of micro-caddis fly (Hydroptilidae) from the Alligator Rivers region, Northern Territory, are described in the genera *Hellyethira, Tricholeiochiton, Oxyethira* and *Orthotrichia;* notes are given on their possible relationships. Collecting data for three species suggest that these show strong seasonality, with two species emerging almost exclusively in the dry season (July), and one in the wet (March).

KEY WORDS: Taxonomy, Trichoptera, Hydroptilidae, Alligator Rivers, seasonality.

Introduction

Regular monitoring of "emergence" traps on three natural water bodies near Jabiru in the Alligator Rivers region, Northern Territory, yielded information on species diversity, seasonality, and diel activity of a number of Trichoptera (Sharley & Malipatil 1985, and unpublished data). Amongst the microcaddis flies (Hydroptilidae) collected (14 species in four genera), were four species which are described here for the first time, and which are referred to the genera *Hellyethira* Neboiss, *Tricholeiochiton* Kloet & Hincks, *Oxyethira* Eaton and *Orthotrichia* Eaton.

Within Australia, *Tricholeiochiton* is known only from the north (Wells 1982), where five species have now been recorded. The genus is elsewhere represented by a single species in the Palaearctic and two species in S.E. Asia (Marshall 1979). The subgenus *Dampfitrichia* in *Oxyethira,* into which one new species is placed, has a similar northern distribution in Australia where four species are now known; it occurs elsewhere in S.E. Asia, the Neotropics, the Palaearctic, and the Western Pacific (Kelley 1984, and pers. comm.). In contrast, *Hellyethira* and *Orthotrichia* are widespread in Australia (Wells 1979a & b, 1983), and now total 18 and 35 known species, respectively. One Australian species of *Hellyethira* is recorded from New Caledonia (Wells unpublished data), and Kelley (1984) has transferred a Japanese species to this genus. *Orthotrichia* is absent from SW Australia, but is especially diverse in the north. Seven species were collected in the Alligator Rivers study (Sharley & Malipatil unpublished data); about 54 species are known from elsewhere in the world.

Emergence data for the three seasons that were monitored, late-dry 1982 (October/November), wet 1983 (March), and dry 1983 (July) (Supervising

Scientist for Alligator Rivers region 1984; Sharley & Malipatil 1985[1]) give some indication of life cycle patterns of a number of species and suggest that three of the new species, at least, are highly seasonal. Interestingly, each of these appears to be more closely allied to a north-eastern than a north-western congener.

Materials and Methods

All material was collected in the Alligator Rivers region, Northern Territory, from three natural water bodies, the Magela Creek (at N.T. Water Division gauging station 821009), Georgetown Billabong and Corndorl Billabong. Trapping methods are described in the Alligator Rivers Region Research Institute, Research Report 1983-84 (Supervising Scientist for Alligator Rivers region, 1984).

Methods for preparation, drawing, and storage of specimens follow Wells (1978). All material, including types, is the property of the Northern Territory Museum of Arts and Sciences, Darwin (NTM), where it is lodged.

Hellyethira veruta sp. nov.
FIGS 1-3

Holotype: NTM I.56♂, Magela Creek, S. of Georgetown Billabong, N.T., 11.vii.1983, A. J. Sharley.

Paratypes: NTM I.57-63 3♂, 4♀ (including allotype I.60) collected with holotype, NTM I.64-89 16♂, 10♀, same locality, A. J. Sharley, 1.vii.1983; NTM I.90 1♀, 27.vi.1983, NTM I.91-94 4♀, 29.vi.1983, Georgetown Billabong, nr Jabiru, N.T., A. J. Sharley; NTM I.95 1♀, 30.iii.1983, NTM I.96 1♀, 22.iii.1983, Corndorl Billabong, nr Jabiru, N.T., A. J. Sharley.

Other material examined: 7♂, 10♀, 27.vi.1983, 2♂, 2♀, 29.vi.1983, 4♂, 10♀, 3.vii.1983, 1♂, 2♀, 5.vii.1983, 4♂, 9♀,

* Department of Zoology, University of Adelaide, G.P.O. Box 498, Adelaide, S. Aust. 5001.

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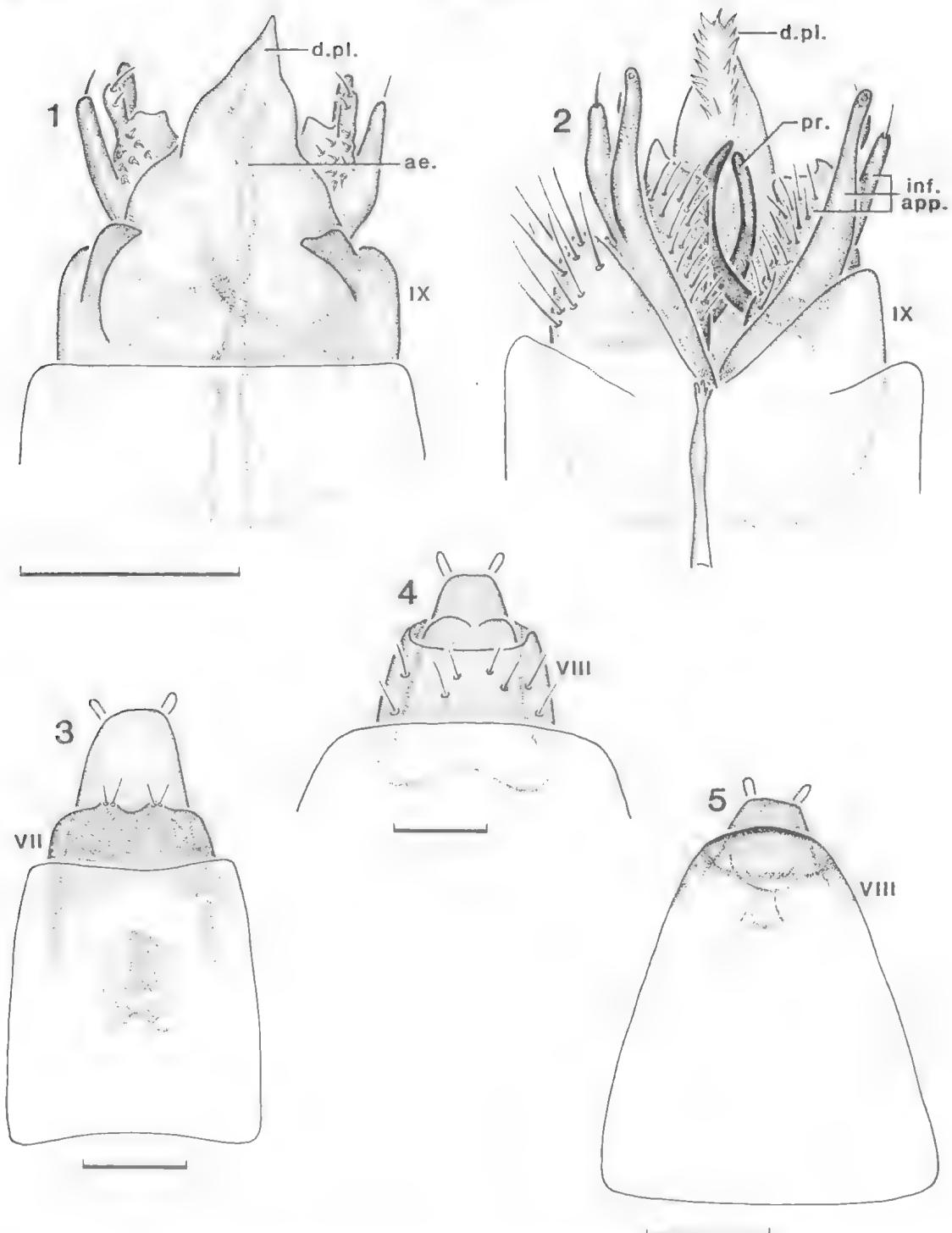
Figs 1–5. *Hellyethira veruta* sp. nov. 1, 2. ♂ genitalia in dorsal and ventral views. 3. ♀ terminalia, ventral view. *Tricholeiochiton jabirella* sp. nov. 4. ♀ terminalia, ventral view. *Oxyethira warrumunga* sp. nov. 5. ♀ terminalia, ventral view. Abbreviations: ae., aedeagus; d.pl., dorsal plate; inf.app., inferior appendage; pr., paramere; VII, VIII, IX, abdominal segments VII, VIII, and IX. Scale bars = 0.1 mm.

7.vii.1983, 2♂, 4♀, 9.vii.1983, 1♀, 3♀, 13.vii.1983, 2♂, 2♀, 15.vii.1983, 1♂, 1♀, 17.vii.1983, 1♀, 1♀, 19.vii.1983, 1♂, 1♀, 21.vii.1983, ♂, 23.vii.1983, 1♀, 1♀, 25.vii.1983, 1♂, 1♀, 20.iii.1983, 1♀, 22.iii.1983, 1♀, 26.iii.1983, 2♀, 28.iii.1983, Magela Creek, S. of Georgetown Billabong, N.T., A. J. Sharley.

Diagnosis: Medium sized, with mottled fawn-cream vestiture.

Male. Length of anterior wing 1.5-1.7 mm. Antennae 30-segmented. Genitalia symmetrical, as in Figs 1, 2. Inferior appendages multilobed, ventral-most lobe elongate, slender, bifid distally; second lobe also slender and elongate; upper lobe plate-like in ventral view, with apicolateral angles attenuated. Dorsal plate membranous, with a median serrate "ruff". Paramere slender, curved, intersecting medially. No subgenital plate evident. Female. Length of anterior wing 1.6-2.1 mm. Terminalia (Fig. 3) short, sternite VII slightly bilobed apicomesally, each lobe tipped by paired setae.

H. veruta shows close similarity to *H. eskensis* (Mosely) and *H. sentisa* Wells (Wells 1979a) which have similar scissor-like parameres. The inferior appendages more closely resemble those of *H. eskensis*, although the dorsal plate of *H. veruta* is distinct from those of the other two species. Hitherto, I considered *H. eskensis* and *H. sentisa* to be close sister species; the precise nature of their relationship to *H. veruta* is unknown, but the three species clearly form a distinct lineage within *Hellyethira*.

H. veruta appears to be quite seasonal: it is absent from late-dry season collections, rare in those from the wet season, and most abundant in the dry season samples. Most specimens were taken from Magela Creek and only few from the two lagoons. At the sampling site Magela Creek has a white sand substrate, and lacks the macrophyte community found in the lagoons; in the dry season the water recedes to form a small stagnant pool in the stream channel (Malipatil pers. comm.).

Tricholeiochiton jabirella sp. nov.
FIGS 4, 6, 7

Holotype: NTM L97 ♂, Corndorl Billabong, nr Jabiru, N.T., 20.iii.1983, A. J. Sharley.
Paratypes: NTM L98 1♂, L99 (allotype) ♀, collected with holotype; NTM L100 1♂, 12.iii.1983, NTM L101 1♀, 16.iii.1983, NTM L102-103 2♂, 18.iii.1983, Corndorl Billabong, nr Jabiru, N.T.; NTM L104 1♂, Georgetown Billabong, nr Jabiru, N.T., A. J. Sharley, 7.iii.1983.

Diagnosis: Medium sized, with mottled wings, tips of wings upturned, R_2 and R_3 arise independently in anterior wings.

Male. Length of anterior wing 2.2-2.5 mm. Antennae 32-segmented. Genitalia as in Figs 6, 7. Segment X short, sternite with broad, deep, median

excavation, lateral lobes sclerotised distally. Dorsal plate trilobed, membranous, central lobe subquadrate. Subgenital plate membranous, broad, narrowly cleft apicomesally. Inferior appendages stout, slightly extended apicomesally to form rounded, sclerotised lobes. Aedeagus with a black spine arising subapically and projecting slightly beyond apex.

Female. Length of anterior wing 2.5 mm. Antennae 22-segmented. Terminalia (Fig. 4) short, pale; segment VIII simple, collar-like.

T. jabirella is most closely allied to *T. fidelis* Wells (Wells 1982) with which it shares the general form of its male genitalia and wing venation. However, it is readily distinguished by the black spine on the aedeagus, broader inferior appendages, and bilobed subgenital plate. Both species were collected from the same localities in the emergence traps. *T. jabirella* appears to be highly seasonal, being taken only in the wet season (March), while *T. fidelis* was collected in all seasons (Sharley & Malipatil unpublished data). Although congeners were collected from lagoons only in the Alligator Rivers region, *T. fidelis* has been taken from rivers and streams in NE Queensland. Both Georgetown and Corndorl billabongs have black clay substrates and macrophyte communities, and have slow flow only in the wet season (Malipatil pers. comm.).

Oxyethira (Dampfitrichia) warramunga sp. nov.
FIGS 5, 8, 9

Holotype: NTM L105 ♂, Georgetown Billabong, nr Jabiru, 21.vii.1983, A. J. Sharley.
Paratypes: NTM L106-109 1♂, 1♀, (including allotype L107), 21.vii.1983, NTM L110-112 3♀, 27.vi.1983, NTM L113-116 1♂, 4♀, 3.vii.1983, NTM L117-118 1♂, 1♀, 15.vii.1983, NTM L119 1♂, 19.vii.1983, NTM L120 1♀, 29.vi.1983, NTM L121 1♂, 27.vii.1983, Georgetown Billabong, nr Jabiru, N.T., A. J. Sharley; NTM L122 1♀, 3.xii.1983, NTM L123 1♀, 29.vii.1983, Magela Creek, S. of Georgetown Billabong, N.T., A. J. Sharley; NTM L124 1♂, Corndorl Billabong, nr Jabiru, N.T., 23.vii.1983.
Other material examined: 1♀, 29.vi.1983, 2♀, 5.vii.1983, 1♀, 9.vii.1983, 2♀, 25.vii.1983, Georgetown Billabong, nr Jabiru, N.T., A. J. Sharley, NTM; 1♀, 26.vi.1983, 1♀, 27.vi.1983, 3♀, 29.vi.1983, 4♀, 1.vii.1983, 3♀, 3.vii.1983, 1♀, 5.vii.1983, 1♀, 9.vii.1983, 1♀, 19.vii.1983, 2♀, 27.vii.1983, Magela Creek, S. of Georgetown Billabong, N.T., A. J. Sharley, NTM.

Diagnosis: Minute caddisflies with mottled vestiture; spur formula 0,2,4.

Male. Length of anterior wing 1.1-1.5 mm. Antennae 26-segmented. Genitalia as in Figs 8, 9. Segment VIII broad, rounded, sternite widely and shallowly excised apicomesally; tergite with a broad, deep mesal concavity. Dorsal plate membranous, rounded, broad at base, narrower distally. Aedeagus stout, without titillator. Inferior appendages discrete distally, fused at base; paired lobes dorsal to inferior
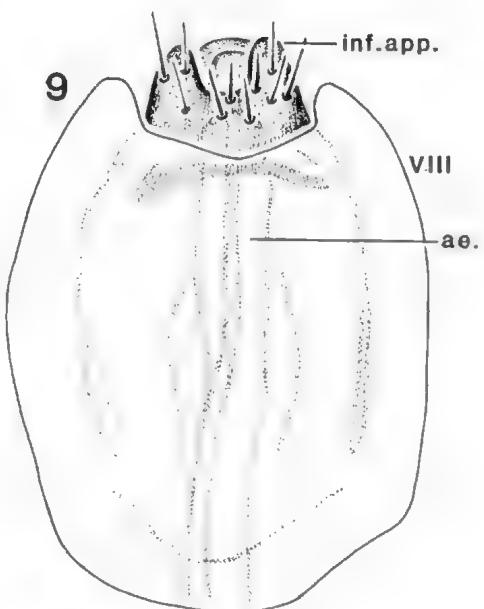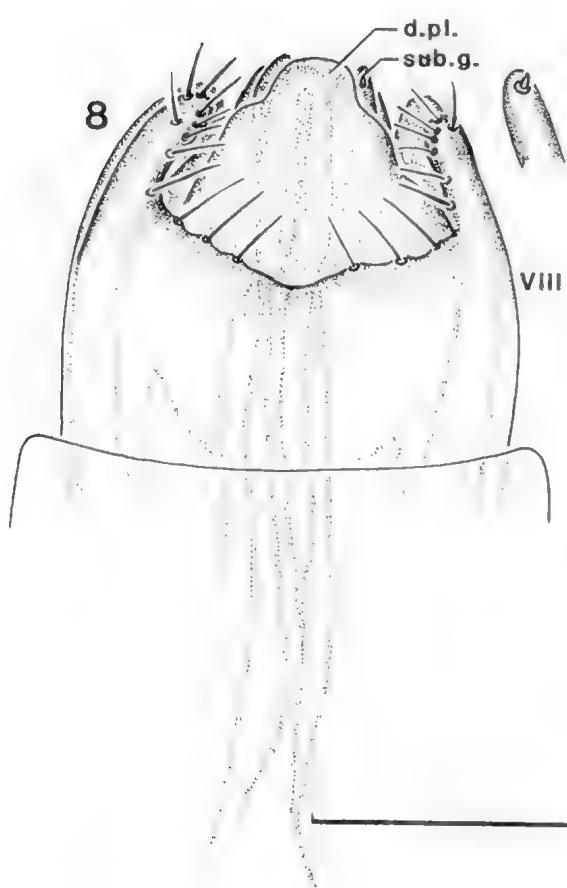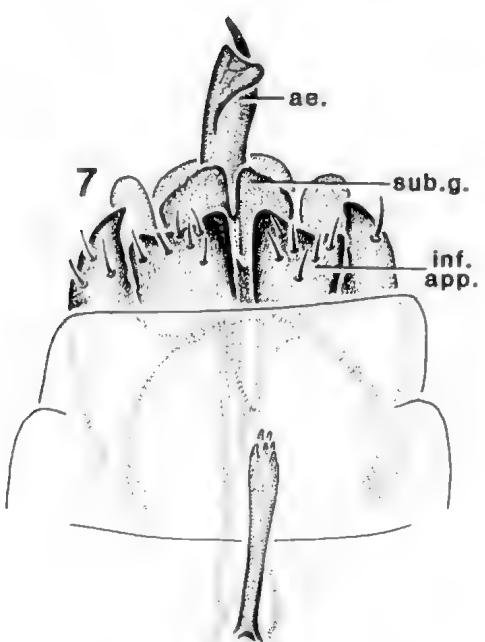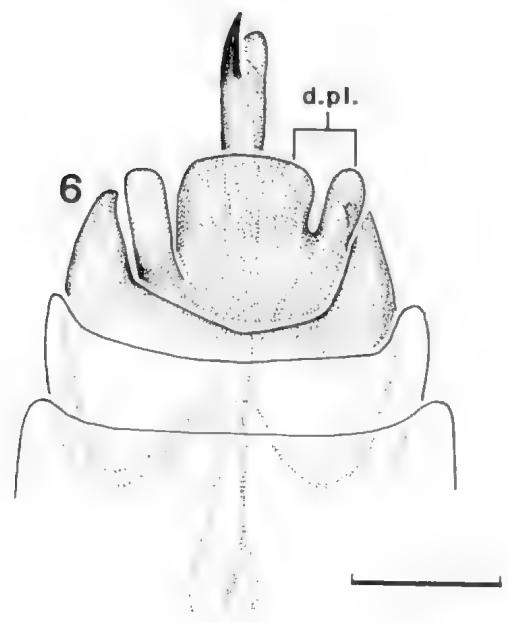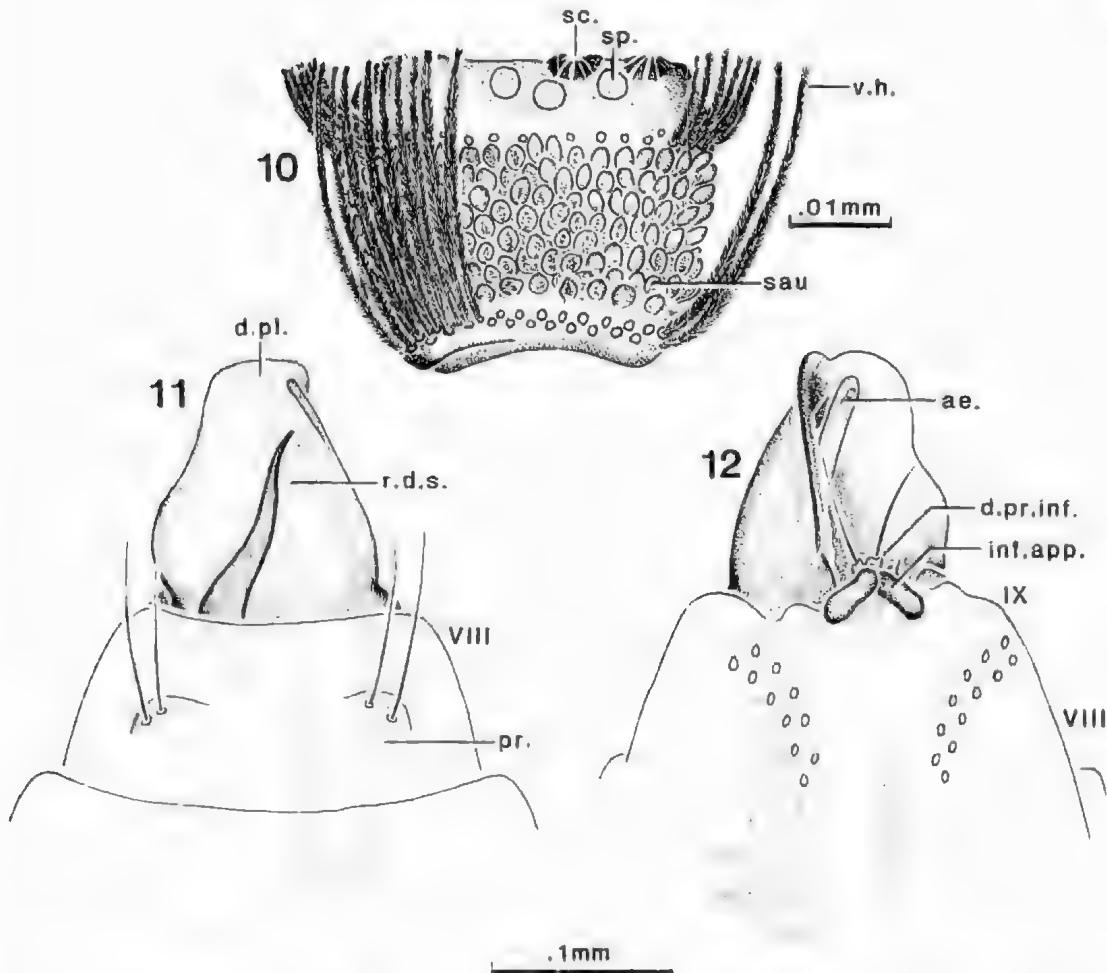
Figs 10-12. *Orthotrichia eurhinata* sp. nov. ♂. 10. 7th antennal segment, dorsal view; 11, 12. genitalia, dorsal and ventral views. Abbreviations: ae., aedeagus; d.pl., dorsal plate; d.pr.inf., dorsal process of inferior appendages; inf.app., inferior appendages; pr., paramere; r.d.s., right dorsal spine; sau., sensilla auricillica; sc., sensilla coeloconica; sp., sensilla placodea; v.h., vestitural hair; VIII, IX, abdominal segments VIII and IX. Scale bars as indicated.

appendages may represent the subgenital plate. Female. Length of anterior wing 1.4–2.0 mm. Antennae 20-segmented; stapes about 2× length of pedicel. Terminalia as in Fig. 5. Sternite VIII triangular, apex with a narrow sclerotised band; tergite shallowly concave apically.

O. warramunga is clearly a member of the *minima* group in *O. Dampfitrichia*, to which two other north Australian species, *O. artuvillosus* (Wells) and *O. plumosa* (Wells), belong (Kelley 1984). However it lacks their distinguishing features—areas of androconia on abdominal tergite VI, elongate hairs on the hind tibiae, and a patch

or border of stout black setae apicomesallly on sternite VIII. The female terminalia of *O. warramunga* are distinguished only by the shallowly concave apex of tergite VIII, compared with the angular vertex of *O. artuvillosus*. In features of male genitalia *O. warramunga* is probably closer to *O. plumosa* than to *O. artuvillosus*.

Only a single specimen was collected in the late dry season, all others were taken in the dry season at all three localities. One male and three females of *O. artuvillosus* were also collected from Magela Creek in the dry season of 1983 (Sharley & Malipatil unpublished data).

Figs 6-9. *Tricholeiochiton jabirella* sp nov. 6, 7. ♂ genitalia, dorsal and ventral views. *Oxyethira warramunga* sp. nov. 8, 9. ♂ genitalia, dorsal and ventral views. Abbreviations: ae., aedeagus; d.pl., dorsal plate; inf.app., inferior appendage; sub.g., subgenital plate; VIII, abdominal segment VIII. Scale bars = 0.1 mm.

Orthotrichia eurhinata sp. nov.
### FIGS 10-12

Holotype: NTM I.125 ♂, Georgetown Billabong, nr Jabiru, 17.vi.1983, A. J. Sharley.

Diagnosis: Known only from a single medium-sized male with distinctive antennae: segments of proximal ⅓ of flagellum stout, broader than long, subsequent segments becoming more elongate towards tip; proximal segments with whorls of vestitural hair on either side of a broad band of sensilla auricillica (Fig. 10), distal segments with incomplete bands or patches of auricillica.

Length of anterior wing 1.7 mm. Antennae 24-segmented; 4 terminal segments dark, preceeded by 1 pale, 4 dark, 2 pale, and 13 dark segments. Genitalia as in Figs 11, 12. Right dorsal spine only present, elongate, tapering and curved across dorsal plate. Dorsal plate rounded apically, wrapping around aedeagus; a small blunt subapical process on dorsum. Inferior appendages small, discrete, symmetrical; dorsal process short, divided apically; basal apodeme elongate slender. Paramere thin, curved.

Female unknown.

O. eurhinata is in the *O. adornata* group in the Australian *Orthotrichia* and is probably closest to *O. bullata* Wells, another north Australian species (Wells 1979b), although *O. bullata* has more elaborate dorsal spines and larger, rounded inferior appendages. The form of the antennae of *O. eurhinata* is quite unique, at least amongst the Australian and New Guinean members of the genus, which have scattered vestitural hair on all segments and large numbers of sensilla placodea (Wells 1984).

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A NEW SPECIES OF UPEROLEIA (ANURA: LEPTODACTYLIDAE) FROM THE PILBARA REGION, WESTERN AUSTRALIA

BY MARGARET DAVIES, M. MAHONY & J. D. ROBERTS

Summary

Uperoleia glandulosa sp. nov., is described from the Pilbara region of Western Australia. The new species is sympatric with U. russelli. Call information and karyotype are included in the species description.

A NEW SPECIES OF *UPEROLEIA* (ANURA: LEPTODACTYLIDAE) FROM THE PILBARA REGION, WESTERN AUSTRALIA

by Margaret Davies*, M. Mahony† & J. D. Roberts‡

Summary

Davies, M. Mahony, M. & Roberts, J. D. (1985) A new species of *Uperoleia* (Anura: Leptodactylidae) from the Pilbara Region, Western Australia. *Trans. R. Soc. S. Aust.* 109(3), 103-108, 29 November, 1985.

Uperoleia glandulosa sp. nov., is described from the Pilbara region of Western Australia. The new species is sympatric with *U. russelli*. Call information and karyotype are included in the species description.

KEY WORDS: *Uperoleia glandulosa* sp. nov., advertisement calls, Anura, Leptodactylidae, karyotype.

Introduction

In revising the genus *Uperoleia* Gray, Tyler, Davies & Martin (1981a) restricted the distribution of the nominate species *U. marmorata* Gray to the type locality "Western Australia", estimated from Gray's journals to be in the Prince Regent River area. Later they recorded the distribution of *U. mjobergi* (Andersson) as confined to the Fitzroy River drainage (Tyler *et al.* 1981b). Hence records of *U. marmorata* and unsubstantiated records of *U. mjobergi* (as *Glauertia mjobergi*) in the Pilbara region of Western Australia (Main 1965; Main & Storr 1966) cannot be sustained.

A third species, *U. russelli* (Loveridge) is recorded from the Pilbara and is considered endemic to the region (Main 1965; Main & Storr 1966; Tyler *et al.* 1981a; Tyler, Smith & Johnstone 1984).

During field work following Tropical Cyclone Jane in January 1983, two of us (J.D.R. and M.M.) collected two species of *Uperoleia* near Port Hedland. One of these species is *U. russelli* and the other is conspecific with the specimen referred to by Main (1965) and Main & Storr (1966) as *U. marmorata* and which is undescribed.

Here we describe the new species and include brief notes on its breeding biology, call and karyotype.

Materials and Methods

Material cited here is deposited in the Australian Museum, Sydney (AM), the South Australian Museum, Adelaide (SAM) and the Western Australian Museum, Perth (WAM).

Measurements of specimens follow Tyler *et al.* (1981a). Measurements taken (in mm) were: eye diameter (E); eye to naris distance (E-N); internarial

span (IN); snout to vent length (S-V) and tibia length (TL).

Osteological data were obtained from cleared and alizarin red S stained specimens prepared after the method of Davis & Gore (1947). Osteological descriptions follow Trueb (1979).

Calls were recorded in the field on a Sony TC-510-2 reel to reel tape recorder, with Beyer M101 or AKG D190 microphones at a tape speed of 19 cm s^{-1}. Six call parameters were analysed in detail: (1) mean call period (seconds) estimated from the time taken to make 20 calls (time taken with a stop watch, half-speed playback; (2) call duration; (3) pulse duration; (4) pulse period; (averaged over the whole call) (2-4, all in milliseconds and measured from oscillograms made on a San-ei 5M28 direct recording oscillograph); (5) pulse number (counted oscillograms); and (6) dominant frequency, averaged over five calls by a Tektronix 5L4N spectrum analyser. For the first five parameters, we analysed five calls from each recorded frog. Pulse durations were estimated from all pulses in the call. Periods rather than repetition rates are reported as these are the basic units measured; repetition rates represent a derived unit (Gaioni & Evans 1984). Repetition rates are a simple reciprocal function of periods. Data for each frog were averaged and the mean values were used to calculate an overall mean. Each individual thus contributes one datum point to the final figures.

Miotic chromosomes were examined from WAM R89489, using the technique described by Mahony & Robinson (1980). Silver staining was carried out following the procedure of Bloom & Goodpasture (1976).

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Uperoleia glandulosa sp. nov

FIGS 1-7

Uperoleia marmorata Main 1965, Frogs of South Western Australia. p. 36 (part); Main & Storr, 1966. W. Aust. Nat. 10, p. 57; Cogger, 1983. p. 84.

Holotype: WAM R89489, an adult male collected

Fig. 1. A lateral, B dorsal view of head of *Uperoleia glandulosa* sp. nov. (SAM R27081).

at Petermarer Creek, Port Hedland-Broome Rd, W.A. (21°23'6"S, 118°48'21"E), on 10.i.1983 by M. Mahoney and J. D. Roberts.

Definition: A moderate sized species (males 20–25 mm, female 25 mm S-V) with moderately long limbs (TL/S-V 0.34–0.41). Maxillary teeth absent; frontoparietal fontanelle widely exposed; basal webbing between the toes; toes fringed; mating call a sharp click.

Description of holotype: Maxillary teeth absent. Vomerine teeth absent. Snout short, truncated when viewed from above and in profile. Eye to naris distance greater than internarial span (E-N/IN 1.36). Canthus rostralis prominent and straight (Fig. 1A). Loreal region sloping. Tympanum not visible externally (Fig. 1B). Fingers moderately long, slightly fringed (Fig. 2A) with well developed subarticular tubercles. In order of length 3>4>2>1. Palmar tubercles large and prominent. Supernumerary palmar tubercles prominent. Hind limbs long (TL/S-V 0.37). Toes long, fringed, with basal webbing (Fig. 2B). In order of length 4>3>5>2>1. Large oval inner and broad outer metatarsal tubercles. Subarticular tubercles conical.

Dorsal surface with well defined parotoid, inguinal and coccygeal glands (Fig. 3). Dorsum faintly tubercular. Submandibular gland disrupted. Ventral surface finely granular.

Male with unilobular, submandibular vocal sac. In preservative, dorsal surface brown. Short cream, midvertebral stripe on anterior 1/3 of body. Black, lyrate markings on scapular region (Fig. 3) and black patches on other portions of dorsum.

Surfaces of parotoid, inguinal and coccygeal glands, cream. Inguinal and femoral regions cream. Ventral surface cream with chocolate brown suffusions. Submandibular region dark brown.

Fig. 2. A palmar view of hand, B plantar view of foot of *Uperoleia glandulosa* sp. nov. (SAM R27081).

Colour in life. Main & Storr (1966) described the colour of WAM R22921 as "Dorsal ground colour olive-brown with black spots and blotches. Anteriorly an indistinct vertebral series of orange spots. Dorso-laterally a broken orange stripe from behind orbit nearly to groin. A small orange spot on each side of sacrum. A large orange red blotch in groin and on outer surface of thigh. Upper surface of limbs as on dorsum. Ventrally whitish flecked with grey. Lower surface of limbs flesh-coloured."

This description conforms with our observations.

Dimensions (in mm): Snout-vent length 20.2; tibia length 7.4; eye diameter 2.8; eye-naris distance 1.9; internarial span 1.4.

Variation: The are seven paratypes, six adult ♂♂ and one adult ♀. WAM R89490-2, AM R114573,

Fig. 3. *Uperoleia glandulosa* sp. nov. in life.

collected with the holotype; SAM R27081, SAM R27082 (cleared and stained), 3.2 km NE Wittenoom turnoff on Port Hedland-Broome Rd, 10.i.1983, M. Mahony, J. D. Roberts. WAM R22921, Mundabullangana (5 km E of Hstd), 19.ii.1961, G. M. Storr.

Males range 19.9–23.4 mm and the female is 24.6 mm S-V. All paratypes are squat with long legs (TL/S-V 0.38–0.41) in the males: 0.34 for the female). E-N/IN ranges 1.13–1.50. All specimens have well developed cream glands, and basal to slightly more than basal toe webbing. Skin texture resembles that of the holotype. The ground colour of the dorsum of the female is grey rather than brown whilst the darker colour markings of all the paratypes are brown whereas the holotype is black. One paratype has a truncated snout when viewed from above, as in the holotype, whereas the others have more rounded snouts (Fig. 1B). In some of the paratypes the midvertebral stripe is not as conspicuous as in the holotype. Palmar tubercles are not always as prominent as figured.

Mating call structure: The advertisement call of this species is a sharp click: a single note formed by two or three pulses. The pulses have a rapid rise time, one or two oscillations, and an irregular decay to about 1/4 of the peak amplitude before the next pulse is initiated. Pulse periods are short (about 6 ms) and equal to pulse durations. Details of call structure are given in Table 1. An oscillogram is presented in Fig. 4.

Breeding biology: Most males were observed calling around a roadside drainage channel. Males were calling at the base of sedge clumps close to the

TABLE 1. *Details of call structure of two* Uperoleia glandulosa *sp. nov. Values are means with standard deviation and range in brackets.*

Temperature T°C	Pulse Number	Pulse Duration (ms)	Pulses sec⁻¹	Call Duration (ms)	Call period (s)	Calls min⁻¹	Frequency (Hz)
25 (Air dry)	2.3 (0.4, 2.0–2.6)	6.3 (0.8, 5.7–6.8)	160	14.2 (0.6, 13.4–14.6)	0.74 (0.08, .69–.8)	81.1	2875 (35, 2850–2900)

water's edge or in a similar position actually in the water. Males with a similar call were also heard in the Petermarer Creek and around a flooded claypan about 3 km southwest of the Turner River on the Northwest Coastal Highway, in the Turner River but not on the Yule River. Males were calling on the third night after two days and two nights of heavy rains (114 mm at Port Hedland).

Uperoleia russelli was calling at the same sites.

Osteology: Skull poorly ossified, sloping anteroventrally. Small portion of sphenethmoid ossified posteriorly to medial extremities of palatines with ossified portion extending about 1/3 of the length of the orbit in ventral view. Medial ossification of sphenethmoid absent dorsally and ventrally. Prootic not fused with exoccipital. Exoccipital not ossified either dorso- or ventro medially. Crista parotica short, stocky, not overlain by otic ramus of squamosal. Carotid canal groove not developed on frontoparietals. Frontoparietal fontanelle extensively exposed, overlapped laterally by frontoparietal elements extending narrowly for 9/10 length of orbit. Anterior margin of fontanelle formed by sphenethmoid and medial cartilaginous elements, at level of anterior ramus of pterygoid. Posterior margin formed by articulating postero-medial extremities of frontoparietals (Fig. 5A).

Nasals moderately ossified, approximately triangular with maxillary processes directed more ventrally than laterally; widely separated medially. Maxillary processes not in bony contact with well developed preorbital processes of very shallow pars facialis of maxillary.

Palatines robust, reduced laterally, abutting and just overlying anterior extremities of sphenethmoid ventrally. Parasphenoid robust, cultriform process elongate, extending anteriorly to ossified portion of sphenethmoid in ventral view (Fig. 5B). Alary processes expanded laterally, at right angles to

10ms

Fig. 4. Oscillographs of advertisement call of *Uperoleia glandulosa* sp. nov.
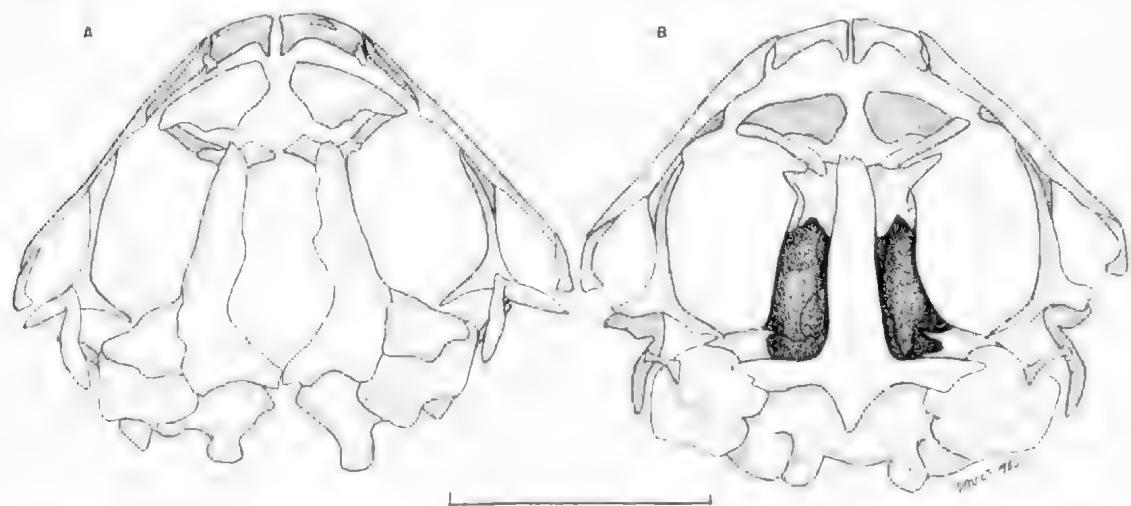
Fig. 5. A dorsal, B ventral view of skull of *Uperoleia glandulosa* sp. nov. (SAM R27082). Scale bar   5 mm.

cultriform process extending almost to level of anterior extremities of medial rami of pterygoids.

Medial ramus of pterygoid moderately long, acuminate, not in bony contact with prootic region. Posterior ramus moderately long and broad. Anterior ramus in long contact with moderately developed pterygoid process of palatal shelf of maxillary. Cartilaginous quadrate present between base of squamosal and quadratojugal. Quadratojugal robust, in firm contact with maxillary.

Squamosal shaft robust; tiny zygomatic ramus, elongate unexpanded otic ramus lying alongside lateral extremities of crista parotica.

Maxillary and premaxillary edentate. Palatal shelf moderately deep with well developed palatine processes not abutting medially, and moderately developed pterygoid processes. Alary processes of premaxillaries moderately broad, bifurcate and perpendicular. Vomers absent. Columella bony.

Pectoral girdle arciferal and robust. Omosternum and xiphisternum present. Sternum cartilaginous. Clavicles slender, curved, poorly separated medially. Scapula bicapitate; about same length as clavicles. Suprascapula about ½ ossified.

Eight non-imbricate presacral vertebrae. Sacral diapophyses poorly expanded. Relative widths of transverse processes III > sacrum > IV > II > V = VI > VII–VIII.

Fig. 6. Lateral view of pelvic girdle of *Uperoleia glandulosa* sp. nov. (SAM R27082).

Bicondylar, sacrococcygeal articulation. Urostyle with crest extending ⅔ its length. Ilia extend anteriorly to sacrum. Ilial crest absent. Large papillate, dorsal protuberance on small dorsal prominence (Fig. 6). Humerus with strongly developed anteroproximal crest. Phalangeal formula of hand 2,2,3,3. Distal tips of terminal phalanges knobbed. Small bony prepollex and palmar sesamoid. Phalangeal formula of foot 2,2,3,4,3. Well developed bony prehallux.

Karyotype: The karyotype of *Uperoleia glandulosa* is shown in Fig. 7; the diploid number is 2n = 24. The chromosomes are arranged in two groups on the basis of size. Pairs 1 to 6 are large with relative lengths (R.L.) ranging from 15% to 9%; pairs 7 to 12 are small with R.L. ranging from 6% to 2%. Chromosome pairs 3, 4, 5 and 8 are submetacentric, with the remaining chromosomes being metacentric. A prominent secondary constriction which is silver stain positive, and thus considered to be the nucleolar organiser region, occurs subterminally on the short arm of chromosome 4. A distinctive secondary constriction mid-way along the short arm of chromosome 8 was not strongly silver positive and is not considered to be a nucleolar organiser region.

Etymology: The specific epithet is from the Latin *glandula* in reference to the prominent parotoid, inguinal and coccygeal glands in this species.

Comparison with other species. Uperoleia glandulosa is distinguished from many congeners by the presence of a widely exposed frontoparietal fontanelle. This feature is shared by *U. arenicola, U. borealis, U. inundata, U. orientalis, U. russelli* and *U. talpa*. All of these species, except for *U. orientalis* for which the data are not known, are "long call" species whereas *U. glandulosa* has a very short call. *U. glandulosa* has a stronger back pattern and less extensive webbing than *U. orientalis*.

From the three "short call" species in Western Australia, *U. lithomoda, U. minima*, and *U. aspera, U.*
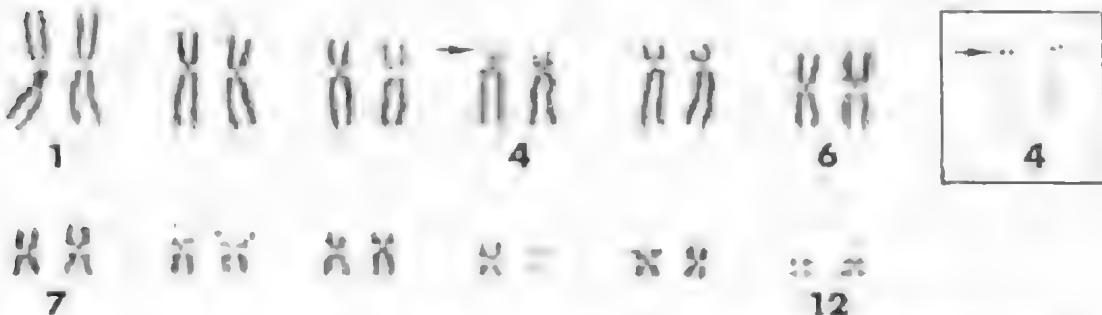
Fig. 7. Karyotype of *Uperoleia glandulosa* sp. nov. Arrows indicate the location of the nucleolar organiser region of chromosome 4; inset shows this region with silver staining. The location of a secondary constriction on chromosome 8 is not silver positive and is indicated by an arrowhead.

glandulosa is distinguished by its greater toe webbing and greater frontoparietal fontanelle exposure.

Discussion

It would appear that the new species that we describe here has been encountered previously at Mundabullangana but misidentified as *U. marmorata* by Main (1965) and Main & Storr (1966). These authors also questioned the identity of some of the material that they assigned to *U. russelli* (as *Glauertia russelli*), considering that it might represent *U. mjobergi*.

No material is available to confirm the existence of a third species in the Pilbara, but during the course of the fieldwork by M.M. and J.D.R., it was thought that a third call type was detected. Hence, although we can now establish that two species are present in the Pilbara (*U. glandulosa* and *U. russelli*), further field work is required to establish if a third species is present.

Although the diploid number, 2n = 24, of several species of *Uperoleia* has been reported (see Morescalchi, 1979 for a summary), to date no karyotype has been figured and chromosome mor-phology has not been described for any species of the genus. Karyotypic examination of 10 species of *Uperoleia* (Mahony & Robinson in press), revealed a striking conservatism of chromosome morpho-logy and, in particular, location of the nucleolar organiser region. While this conservation means that species of *Uperoleia* cannot be distinguished from one another chromosomally, the consistent location of the nucleolar organiser region is a distinctive feature of the karyotypes of *Uperoleia* species, enabling them to be distinguished from all other myobatrachine genera.

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THE AUSTRALIAN NAUCORIDAE (INSECTA, HEMIPTERA-HETEROPTERA) WITH DESCRIPTION OF A NEW SPECIES

BY IVOR LANSBURY

Summary

The Naucoridae of Australia are redescribed and keys to genera and species are provided. A new species, Naucoris subaureus sp. nov. is described from Western Australia. Lectotypes are designated for Naucoris australicus Stål and N. subopacus Montandon. Distributional and ecological notes are given for all six species.

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Summary

LANSBURY, I. (1985) The Australian Naucoridae (Insecta, Hemiptera-Heteroptera) with description of a new species. *Trans. R. Soc. S. Aust.* **109**(3), 109-119, 29 November, 1985.

The Naucoridae of Australia are redescribed and keys to genera and species are provided. A new species, *Naucoris subaureus* sp. nov. is described from Western Australia. Lectotypes are designated for *Naucoris australicus* Stal and *N. subopacus* Montandon. Distributional and ecological notes are given for all six species.

KEY WORDS: Naucoridae; *Naucoris*, *Aphelocheirus*, distribution.

Introduction

The described Australian naucorid fauna of five species (*Naucoris australicus* Stal (1876), *N. congrex* Stal (1876) and *Aphelocheirus australicus* Usinger (1936) from Queensland, *N. subopacus* Montandon (1913) and *N. rhizomatus* Polhemus (1984) from the Northern Territory) is relatively depauperate compared with that of New Guinea. La Rivers (1971) lists 20 endemic species in eight endemic genera, from that area.

Naucoris Fabricius is an 'Old World' genus with *ca.* nine species recorded from the Oriental Region. It has not been recorded from New Guinea or New Zealand.

The inclusion of *Aphelocheirus* Westwood in the Naucoridae is debatable. China & Miller (1959) and Popov (1970) included the genus in the Naucoridae subfamily Aphelocheirinae. However, Poisson (1957) considered the genus merited family status and its omission by La Rivers (1971) from his world checklist of Naucoridae implies acceptance of this contention. A recent review by Hoberlandt & Štys (1979), retained *Aphelocheirus* in a subfamily of the Naucoridae.

Polhemus (1984) briefly reviewed the Naucoridae of Australia. In this paper, I redefine the Australian species of the Naucoridae, including *A. australicus*, and describe a new species of *Naucoris* from Western Australia.

All measurements given are in mm.

Key to Australian genera of Naucoridae

Vertex evenly rounded between the eyes (Figs 1, 7 & 8). Fore femur incrassate (Fig. 55). Rostrum short, not reaching the fore coxae. Antennae short, three-segmented and not visible from above . . . . *Naucoris* Fabricius 1775
Vertex produced between the eyes (Fig. 62). Fore femur not incrassate (Figs 63 & 64). Rostrum long, reaching

the mid-coxae. Antennae long, four-segmented, often visible from above . *Aphelocheirus* Westwood 1833

Naucoris Fabricius

Body variably flattened dorso-ventrally. Fore femur broadly triangular and incrassate, fore tibia folding into a shallow sulcus along femoral margin. Mid and hind legs "cursorial". Antennae three-segmented lying beneath eyes on underside of head. Rostrum three-segmented, two segments visible, not reaching fore coxae. Fore legs separated by a prominent pilose ridge produced cephalad. Between mid and hind coxae, small plate-like keel, not readily visible when viewed from side. Head and pronotum variously punctate light and dark brown; anterior margin of pronotum more or less straight. Clavus and corium unicolorous or bicolored; membrane not always clearly differentiated from corium and emboliar fracture not always entire. Underside of abdomen variably pubescent. Ventral latero-tergites shining, width variable, always becoming obsolescent at apical margin of third sternite, posteriorly reaching seventh sternite. Sternites divided by fold or suture either side of mid-line (Fig. 2). Male genital capsule "boat-shaped", laterally heavily sclerotised, apically membranous. Parameres asymmetrical. Male fifth sternite medianly asymmetrical. Female operculum slightly rounded and distally emarginate. Within Australia, *Naucoris* is of a fairly uniform appearance.

Key to the Australian species of *Naucoris*

1 Posterior margin of pronotum not produced caudad at humeral angles (Figs 1, 7, & 8). Venter either appearing bare or with fine short hairs . . 2
Posterior margin of pronotum produced caudad at humeral angles (Fig. 41). All abdominal ventrites clothed in fine golden pubescence
. . . . *N. subaureus* sp. nov.
2 (1) Scutellum and most of embolium pale yellow (Fig. 1) . . . . *N. australicus* Stal
Scutellum unicolorous dark reddish brown or black, embolium basally variably pale yellow to

* Hope Entomological Collections, University Museum, Oxford, U.K.
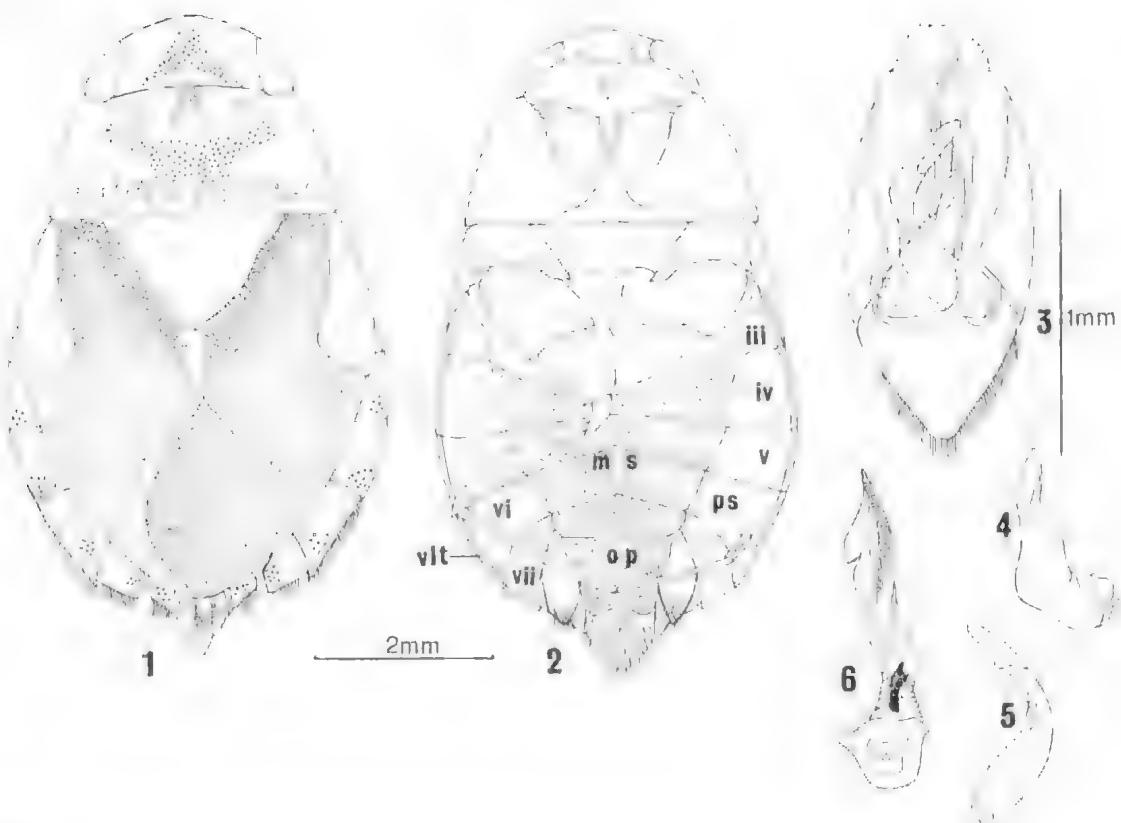
Figs 1-6. *Naucoris australicus* Stål; 1, dorsum and 2, venter of Lectotype ♀. 3, genital capsule and 4, 5, left and right parameres; 6. aedaegus of ♂, Eidsvold, Qld; ms, median sternite; op, operculum; ps, parasternites; vlt, ventral latero-tergites; iii-vii sternites.

yellowish brown, apically always dark brown to black (Fig. 7) 3

3 (2) Posterior angles of connexiva 4-6 sharply produced (Fig. 10). Shining area of 3rd ventral latero-tergite basally broader than anterior width of 4th and broadly infuscated (Fig. 39) .... *N. rhizomatus* Polhemus Posterior angles of connexiva 4-6 not sharply produced (Fig. 9). Shining area of 3rd ventral latero-tergite not basally broader than anterior width of 4th and not broadly infuscated (Figs 35-38)   4

4. (3) Dorsum of head and pronotum rugulose and rather dull. Shining area of ventral latero-tergites narrow (Figs 9 & 38) *N. subopacus* Montandon Dorsum of head and pronotum smooth and usually shining. Shining area of ventral latero-tergites broad (Figs 35-37) .. *N. congrex* Stål

Naucoris australicus Stål
FIGS 1-6, 26, 32-34, 51

Naucoris australicus Stål, 1876, p. 145; Lundblad, 1933, p. 62; La Rivers, 1971, p. 71; Polhemus, 1984, pp. 157-158.
Lectotype: Female, Austral boreal, Thorey; 1 ♂ and

1 ♀ paralectotypes Australia Orient med. Thorey in the Riksmuseum, Stockholm, vid.
Distribution: Queensland.

Male 8.0-9.6 long, width 5.3-5.7. Female (lectotype) 9.5 long, width 5.7.
Colour: Head, pronotum, scutellum and most of embolim pale yellow. Head shining with a triangular group of shallow brown punctures. Pronotum shining, medianly faintly and irregularly transversely striated; anterior margin dark brown, groups of brown punctures converging from inner margin of eye towards the median line posteriorly. Between these groups of punctures, third group of larger darker punctures; posterior margin slightly darker with short irregular rows of shallow contiguous brown punctures. Clavus, corium, apical region of embolium and membrane brown with obsolete narrow, yellowish-brown stripes extending from between the embolium and claval suture almost to membrane. Connexiva pale yellowish brown, distal angles faintly infuscated with irregular prominent brown spots. Underside and legs pale yellow.
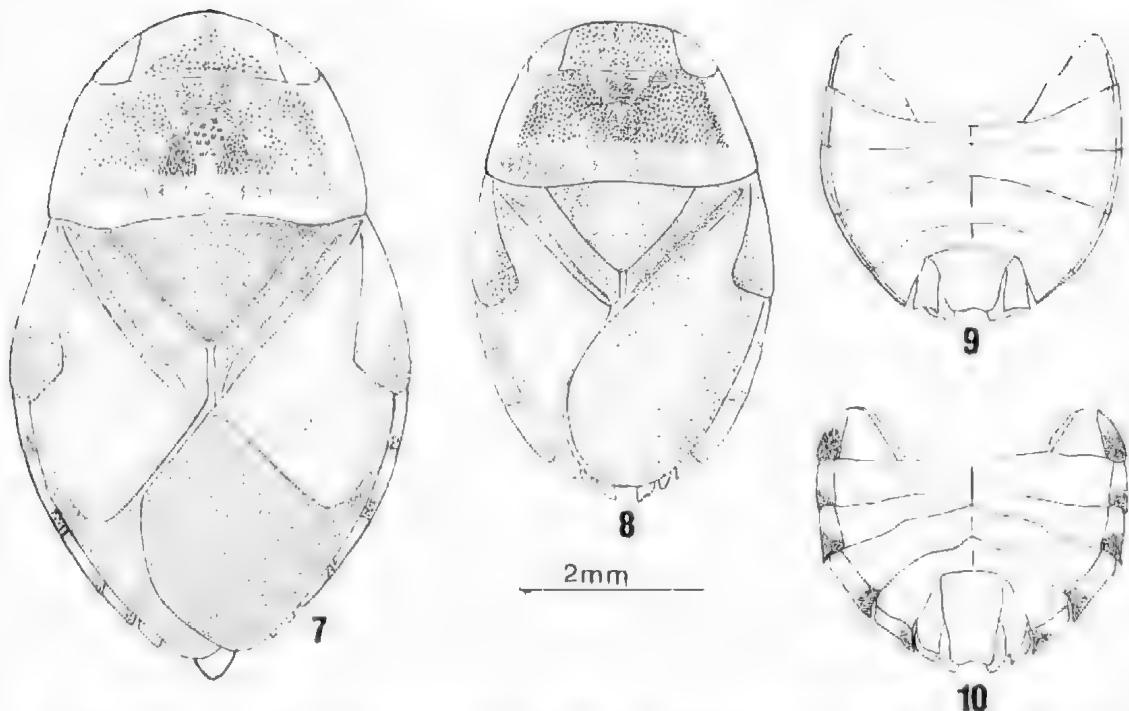
Figs 7-10 *Naucoris* spp.; 7, *N. congrex* Stål ♀ dorsum, Moggill Farm, Qld; 8 *N. subopacus* Montandon ♂ dorsum, Fogg Dam, N.T.; 9, *N. subopacus* Montandon ♀ abdomen, Adelaide River, N.T.; 10, *N. rhizomatus* Polhemus ♀ abdomen, Adelaide River, N.T.

Structure: Anterior interocular space almost the same as posterior. Pronotal humeral width 2.3–2.4× median length, the latter between 1.4–1.8× head length. Pronotal lateral margins slightly convex. Scutellum between 1.5–1.8× broader than long, lateral margins sinuate. Labrum 1.5–1.7× broader than long. Mesosternum conspicuous, slightly produced cephalad. Postero-lateral angles of the fourth and fifth connexiva forming an approximate 90° angle, sixth and seventh slightly produced, the sixth more prominent in the female (Fig. 1). Depression of seventh parasternite conspicuous, almost reaching outer margin of sternite. Male fifth sternite (Fig. 26). Shining lateral margin of third ventral latero-tergite narrow (Figs 32–34). Female seventh sternite about 2/3 median length of sixth (Fig. 2). Operculum (Fig. 51) about 1.3× broader than long. Male genitalia (Figs 3–6).

Material examined: Lectotype female, Austral boreal, Thorey (Stockholm). One ♂, Queensland, Eisvold; one ♂ 'Queensland' (British Museum, Natural History).

Polhemus (1984) gives data for a single male from Qld, 14 miles NW of Ayr, 20 m, 14.xi.1962; E. S Ross, E. Q. Cavagnaro. This specimen in the J. T. Polhemus collection.

Stål's 1876 account of *Naucoris* is confusing where it refers to Australian species. He distinguished *N. australicus* from *N. congrex* because the former had a pale scutellum ("scutello pallido"). In the original description he refers to a male. The type series received from Stockholm has a female labelled TYPUS, the other two specimens have dark brown scutella and are referable to *N. congrex*. The female labelled TYPUS is hereby designated Lectotype and is labelled as such as it is the only specimen which agrees with Stål's description. The remaining male and female labelled "Australia Orient and Thorey" are hereby designated paralectotypes of *N. australicus* although they are in fact *N. congrex*.

The slender data available suggest that *N. australicus* is confined to Qld.

Naucoris australicus is similar in general appearance to *N. congrex*. It is easily distinguished by the pale yellow scutellum and embolium. Across the widest part of the body it has three prominent pale spots, shared by no other Australian naucorid.

Woodward *et al.* (1970) Fig. 26, 72c, figured *N. australicus*, not *N. congrex* as stated.

Naucoris congrex Stål
FIGS 7, 11–25, 27–28, 35–37 & 50

Naucoris congrex Stål, 1876, p. 145; Lundblad, 1933, p. 62; La Rivers, 1971, p. 71; Polhemus, 1984, pp. 157–159.
Holotype: Female, Moreton Bay in the Riksmuseum, Stockholm, vid.
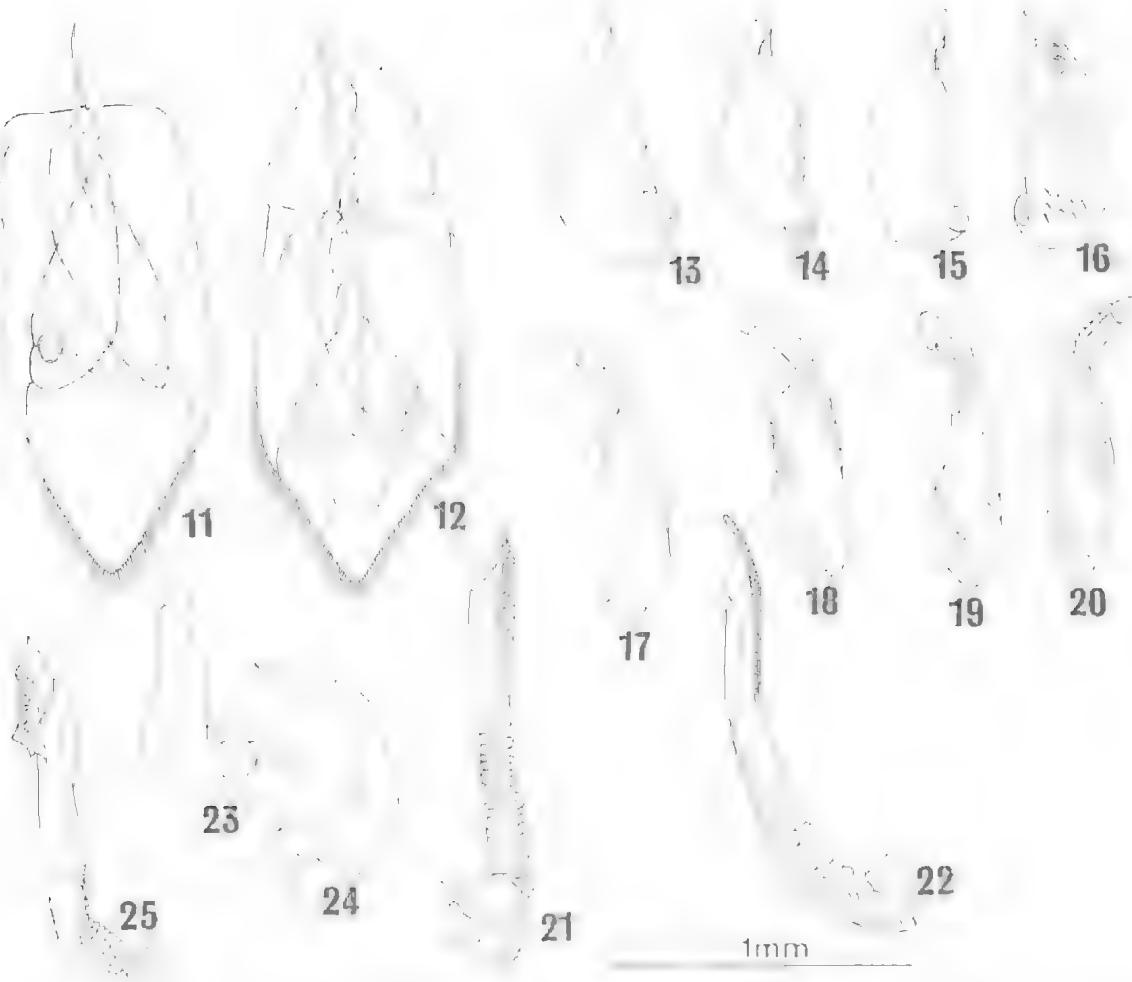
Figs 11-25. *Naucoris congrex* Stål male genitalia; 11, 13, 16, 17, 20 & 21, Tasmania, Tomahawk River; 12, 14, 18 & 22, Victoria, Yea River; 15, 19, South Australia, Piccaninie Blue ponds; 23-25, *"australicus"* part of type series - *congrex*; (11-12) genital capsules; 13-16 & 23, left paramere, 16, different aspect; 17-20 & 24, right parameres, 20, different aspect; 21, 22 & 25, aedeagus.

Distribution: Tas., Vic., S. Aust., N.S.W. and Qld. Males 7.7-8.7 long, width 4.8-5.3. Females 8.5-9 long, width 5.4-6.

Colour: Occurs in two forms as follows. Dark form, head and pronotum yellowish-brown and shining. Head with a broad band of brown punctures tapering or converging towards anterior margin. Pronotum anteriorly, irregularly, transversely striate with shallow brown punctures; centre of disc with scattered larger punctures; posterior 1/3 finely striate with short rows of punctures coalescing into brown lines; lateral margins smooth. Scutellum varying reddish-brown and black; inner lateral margins of clavus pale. Embolium basally pale yellow, apically verging towards corial colour. Membrane dark brown to black with many greyish punctures. Connexiva pale yellow, slightly infuscated posteriorly with dark brown punctures. Pro- meso and metasternum mostly black; lateral margins or mesosternal ridge yellow. Ventrites black with silvery hairs. Ventral parasternites dark brown with crescentic pale yellow indentations across ventrites. Legs pale yellow.

Pale form: Head and pronotum pale yellow background, brown punctures on head reduced in density and coverage, wholly confined to basal half of head. Pronotal pattern reduced; brown stripes on posterior 1/3 almost obsolete. Clavus and corium brown, membrane black. Scutellum as in dark form. Prosternum straw-coloured; coxal plates slightly pigmented. Sternites dark yellowish-brown.

Structure: Anterior interocular space slightly

narrower than posterior space; inner lateral margin of eyes almost straight. Head width to length ratio: males 3.1–4.1× greater than length, average 3.4x. Females 2.4–4×, average 3.5×. Pronotal humeral width 2.2–2.5× median length, average 2.4; latter about twice median length. Pronotal lateral margins evenly curved. Scutellum between 1.5–1.7× broader than long, lateral margins slightly sinuate. Labrum between 1.3–1.8× broader than long, average 1.5 ×. Mesosternum similar to *N. australicus*. Postero-lateral angles of connexiva forming 90° angles; sixth connexiva slightly produced in female (Fig. 7). Depression of seventh parasternite large reaching inner margin of ventral latero-tergite. Male fifth sternite (Figs 27 & 28), little variation between Tas. and Qld forms. Shining lateral margin of third latero-tergite broad (Figs 35–37). Female fifth and sixth sternites same length, seventh sternite 2/3 length sixth sternite. Operculum basally irregularly emarginate (Fig. 50). Male genitalia (Figs 11–25).

Slight variation between Tas. and mainland forms.

Material examined: Holotype female, Moreton Bay (Queensland) Riksmuseum, Stockholm. Tas.; Georgetown, G. E. Cole; Launceston; Wedge Bay, C. H. Hardy, South Australian Museum. Pawleena Lagoon, Coal River; Pond at Karanja; Blackmans Lagoon; Tomahawk River; Cape Portland Lagoon; Icena Lagoon; Moriarty; Newnham; St Bernard's Creek; Flinders Island, Lagoon at Emita; lagoon near Robinson's Farm; North East coastal lagoon; King Island, Lake Flanagan; the preceding via Dr P. S. Lake, and now in the Australian National Insect Collection (ANIC) Canberra.

Vic.: Yallock Creek near Melbourne; farm Dam, Hammano road near Neerim (some adults teneral also immatures); farm dam near Bunyip River, Labertouche North (immature); Lake Purumbete; *Eleocharis* swamp about 8 km from Colac; farm dam about 2 km from Barwon Downs (immature); billabongs along margins of Barwon River at Inverleigh; "Sheepwash" lagoon between Cathkin and west of Molesworth, Yea Rd; backwater of Yea River at Yea (25–29.iii.1979, I. Lansbury) (ANIC, Canberra); Noble Park, 6.iv.1918, F. E. Wilson (SAM). S. Aust.: Adelaide, H. M. Hale; River Torrens, Murray Bridge, H.M.H.; Bridgewater, H.M.H.; Lucindale, A. M.
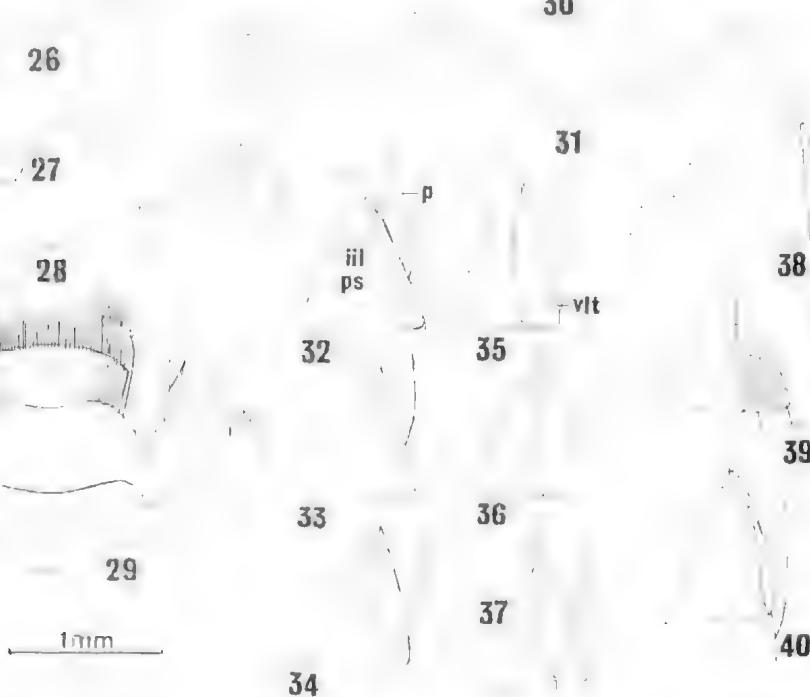
Figs 26–40 *Naucoris* spp. male 5th sternite of 26, *N. australicus* Stål, Qld; 27, *N. congrex* Stål, Tomahawk River, Tas.; 28, *N. congrex* Stål, Moggill Farm, Qld; 29, *N. subaureus* sp. nov. Millstream, Qld; 30, *N. rhizomatus* Polhemus, Coomalie Creek, N.T.; 31, *N. subopacus* Montandon, Fogg Dam, N.T. 3rd ventral laterotergite of 32, *N. australicus* Stål, Lectotype female; 33, *N. australicus* Stål, male, Eidsvold, Qld; 34, *N. australicus* Stål, male, Qld; 36–37, *Naucoris congrex* Stål; 35, Holotype female; 36, male, Tomahawk River, Tas.; 37, male, Moggill Farm, Qld; 38, *N. subopacus* Montandon, male, Fogg Dam, N.T.; 39, *N. rhizomatus* Polhemus female, Adelaide River, N.T.; 40, *N. subaureus* sp. nov. Holotype male, Millstream, Qld. Terminology p protonum; iii ps 3rd parasternite.

Lea; Roonka Sta., Blanchetown, in shallow water along edge of Cumbunga Creek, 12.v.1973, R. Inns (SAM), Mt Gambier region, Piccaninie Blue ponds near Glenelg River, 20.iv.1979, I. Lansbury; "Ewens" ponds near Mt Gambier, 21.iv.1979, I.L.; Naracoorte region, Hack's Swamp near Bool Lagoon, 23.iv.1979, I.L.; same data, Bool Lagoon, 23.iv.1979, I.L.; Kangaroo Island, river just beyond Karratta on road to Kingscote, 9.iv.1979, I.L. (ANIC, Canberra).

Qld: Cunnamulla, H. Hardcastle (SAM); Atherton Tableland, 5 km from Mareeba on Molloy-Mareeba road, 22.v.1979, I.L.; Brisbane, Moggill Farm dam, 6.iv.1979 (some immature) I.L. (ANIC, Canberra).

A male from Tasmania, Tomahawk River, 2.xi.1972, B. Knott has a pair of tunnel-like structures made with detritus and what seem to be short naucorid hairs lying along the 2nd/3rd episternal suture where the middle coxae articulate within the thoracic cavity. These structures are almost certainly phoretic in origin; no remains of any organism were found.

The broad shining lateral margin of the third ventral latero-tergite in both sexes and the conspicuously asymmetrical fifth sternite of the male are diagnostic.

Naucoris subopacus Montandon
FIGS 8, 9, 31, 38, 53, 7, 56-61

Naucoris subopacus Montandon, 1913, pp. 223-224; Lundblad, 1933, p. 62; La Rivers, 1971, p. 71; Polhemus, 1984, p. 160.

Lectotype: Female and three ♀♀ paralectotypes, Northern Territory, Adelaide River, in the British Museum (Natural History) vid. Two female paralectotypes, same locality SAM, vid.

Distribution: W.A., N.T. and Qld.

Males 6.6–6.9 long, width 4–4.2. Females 6.6–7.6 long, width 4.3–4.6.

Colour: Dark form; head dark yellow with brown punctures, finely rugulose appearing dull, in artificial light rather more shining. Pronotum medianly rugulose; most of anterior 1/3 and middle 1/3 covered with brown punctures; anteriorly divided with pale triangular area; within paler area, group of shallow brown punctures with many longitudinal brown stripes posteriorly. Lateral margins smooth yellowish-brown. Scutellum pitchy, reddish-brown to black with faint reddish-brown area medianly. Clavus and corium reddish-brown; dark specimens from Fogg Dam, N.T. have obsolete yellowish-brown patches. Embolium apically yellow merging into corial colour. Membrane blotchy yellowish-brown, membrane of left hemielytron smokey-brown. Connexiva yellowish-brown, posteriorly lightly infuscated. Mesosternum laterally yellow, otherwise dark brown to black. Metasternum dark reddish-brown. Median sternites reddish-brown, ventral latero-tergites suffused with
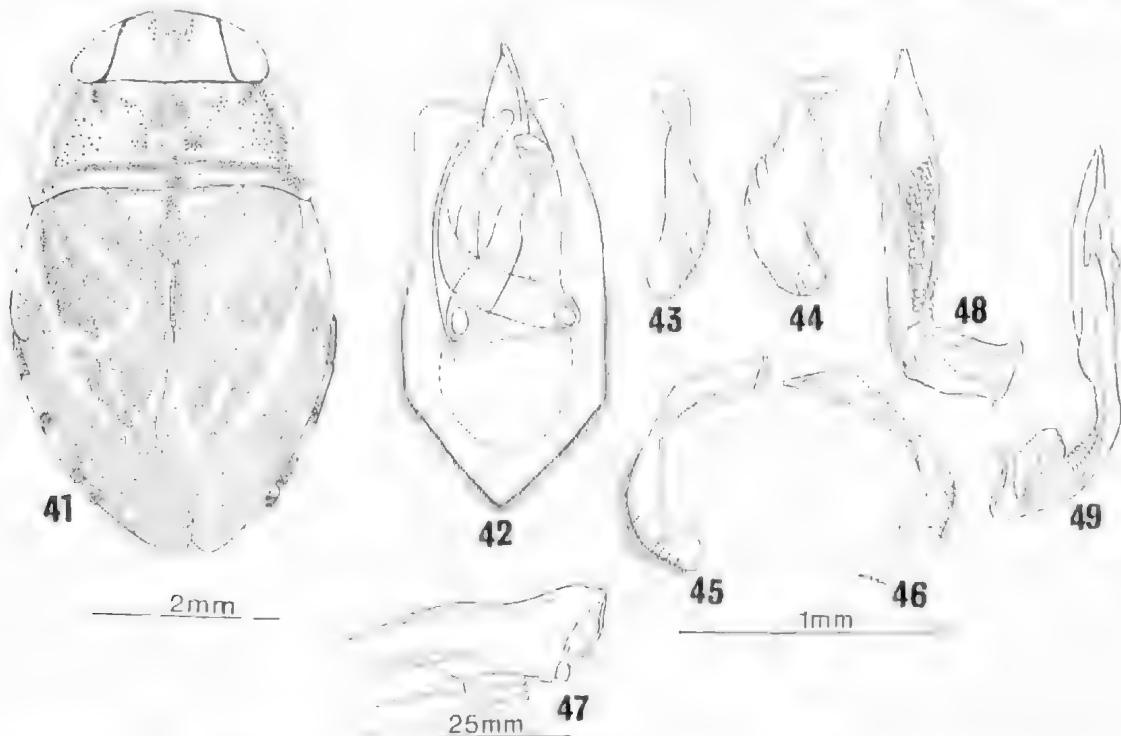
Figs 41-49. Naucoris subaureus sp. nov. Holotype male, Millstream, Qld 41, dorsum; 42, genital capsule; 43-44, left paramere; 45-46, right paramere; 47, apex of Fig. 45; 48-49, aedeagus.

crescentic yellow indentations. Legs yellowish-brown.

Pale form: Head and pronotum pale yellowish-grey, brown spots on head not scattered but in groups either side of mid-line. Punctate area of pronotum not so clearly differentiated from background colour; pattern similar but almost obsolete. Scutellum paler. Irregular yellowish markings on clavus and corium obsolete. Connexiva greyish-yellow with faint infuscation along posterior margins. Underside paler; mesosternum almost completely pale yellow, metasternum tinged with reddish-brown along keel. Pigmentation of dorsum decidedly fugitive, fading rather quickly. Dark areas of head and pronotum fade rapidly leaving sculpturing and rugulose areas. Connexiva tend to fade to uniform greyish-yellow and scutellum loses its almost black colouring post-mortem.

Structure: Anterior interocular distance always less than posterior interocular space. Inner margin of eyes converging anteriorly (Fig. 8). Greatest width of head 3-4× median length; variation in part due to position of head post-mortem; card-mounted specimens have head pushed forward in front of pronotum. Fresh or "wet" specimens tend to have head "dipping" below level of pronotum. Pronotal humeral width between 2.25-2.5× median length, latter being ca. 2× median length. Pronotum elevated or "hump-backed", lateral margins diverging, sometimes strongly rugulose with conspicuous irregular sculpturing over most of disc. Scutellum finely punctate; male about 1.7× broader than long, female 1.6-1.9×. Postero-lateral angles of connexiva broadly exposed forming approximate 90° angle. Labrum 1.4-1.7× broader than long. Mesosternal ridge prominent, clearly produced cephalad. Male fifth sternite slightly asymmetrical. Sternites five and six of male with long hairs; remainder of sternites dark, tomentose. Fifth female median sternite slightly shorter than sixth, seventh not as long as fifth (Fig. 9). Operculum (Fig. 53). Shining area of third ventral latero-tergite narrow (Fig. 38). Male genitalia (Figs 56-61).

Lectotype designation: The type series of *Naucoris subopacus* comprises two species, *N. subopacus* and *N. rhizomatus.* Montandon did not designate any specimen as Type. A female labelled North Australia, Adelaide River, Adelaide River Station, July 14-18th, 1891, J. J. Walker is hereby designated and labelled Lectotype. Three females with identical data are designated paralectotypes. All the foregoing are in the British Museum Natural History. A further female paralectotype in the South Australian Museum has been designated which was originally part of Montandon's syntypic series. A sixth female from North Australia,

Adelaide River, Adelaide River Station, 8-13th August, 1890, J. J. Walker is labelled and designated paralectotype of *N. subopacus* although it is in fact *N. rhizomatus.* All the preceding material was collected during the Voyage of H.M.S. Penguin 1890-1893 and presented to the British Museum by the Lords of the Admiralty, 1896.

Material examined: N.T.: Koolpanyah, G. F. Hill; 30 miles east of Darwin, G.F.H., SAM. McMinns lagoon near Darwin, 4-16.v.1979, I. Lansbury; Fogg Dam near Darwin, 4-16.v.1979, I.L.; billabong near Nourlangie Rock, Kakadu National Park, 10.v.1979, I.L.; Arnhem Highway, Mary River pools, 17.v.1979, I.L. ANIC, Canberra. Jabiluka area, Magela Creek floodplain, Buffalo billabong, 22.i.1979 (immature) R. Tait; same data, 20.vii.1979; Jabiluka Billabong, 17.iii.1979 (immature); same data, 15.v.1979 (immature); Nankeen Billabong, 13.iii.1979; Winmurra Billabong, 14.iv.1979, R. Tait. ANIC Canberra. Qld: Split Rock, 14 km south of Laura, 23-26.vii.1975, G. B. Monteith QM, Brisbane.

W.A.: Beverley Springs, 1.ix.1969, D. D. Giuliani; WAM, Perth.

Naucoris subopacus is a small robust species; the broadly exposed connexiva and narrow shining third ventral latero-tergite distinguish *N. subopacus* from the rest of the genus within Australia.

Naucoris rhizomatus Polhemus
FIGS 10, 30, 39 & 52

Naucoris subopacus Montandon, 1913, pp. 223-224 (partim.)
Naucoris rhizomatus Polhemus, 1984, pp. 157-158.

Holotype: Male, N.T., near Darwin, Coomalie Creek, 11.xii.1977, J. T. Polhemus, in the ANIC, Canberra. Paratype male and female originally deposited in Oxford (Polhemus, 1984: 157) is now in ANIC, Canberra.

Superficially this naucorid resembles *N. subopacus.* The latter has narrow shining latero-tergites (Fig. 9); those of *N. rhizomatus* are broad, distally infuscated. The lateral margin of third latero-tergite basally much broader than apex of fourth (Fig. 39); this feature common to both sexes. Scutellum relatively shorter than in *N. subopacus,* always 2× broader than long; lateral margins more rounded and apex far less acuminate than in *N. subopacus.* Mesosternal ridge more produced cephalad. Male fifth sternite (Fig. 30). Female operculum (Fig. 52).

Material examined: One ♀ paralectotype of *N. subopacus,* N. Australia, Adelaide River, Adelaide River Station, 8-13th August, 1890, J. J. Walker SAM.
N.T.: Jabiluka region, Magela floodplain, Buffalo Billabong, 22.i.1979, R. Tait, 1 immature, connexival markings prominent; same data, 20.vii.1979, 1 ♂ taken with 3 *N. subopacus.*

Polhemus (1984) describes the habitat where *N. rhizomatus* was found in Australia as a deep water creek, the bugs being found amongst the tangled roots of *Pandanus. Naucoris subopacus* tends to be found in shallow weedy habitats. The slender
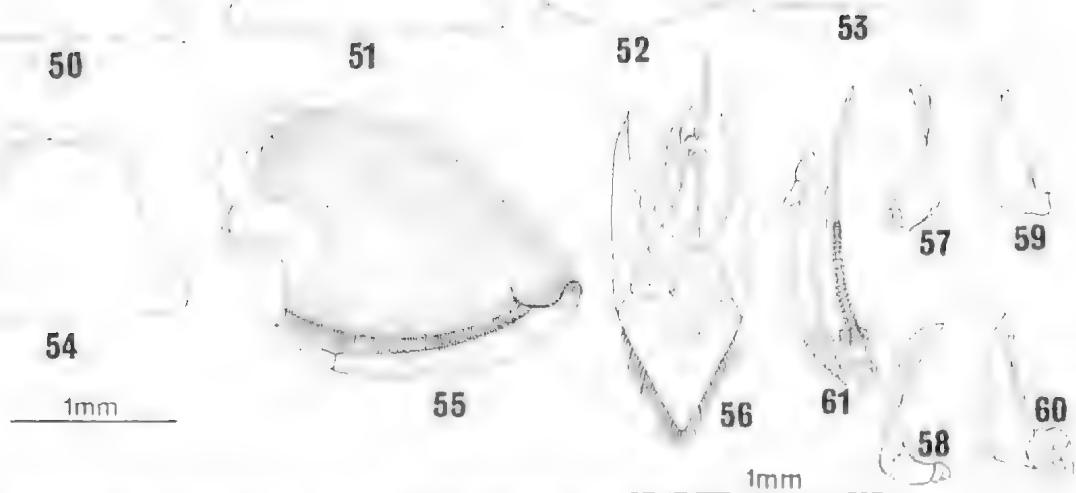
Figs. 50-61. Female operculum of 50, *Naucoris congrex* Stål, Holotype; 51, *N. australicus* Stål, Lectotype; 52, *N. rhizomatus* Polhemus Adelaide River, N.T.; 53, *N. subopacus* Montandon, Adelaide River, N.T.; 54, *N. subaureus* sp. nov. paratype, Millstream, Qld. 55, *N. subaureus* sp. nov. fore leg, Holotype male, Millstream, Qld. *N. subopacus* Montandon, male genitalia, 56, 57, 59 & 61 Fogg Dam, N.T., 58 & 60, 30 miles east of Darwin, N.T. 56, genital capsule; 57, 58, right paramere; 59, 60, left paramere; 61, aedeagus.

evidence suggests that occasionally *N. subopacus* and *N. rhizomatus* occur in the same habitat.

Naucoris subaureus sp. nov.
FIGS 29, 40-49, 54 & 55

Holotype: Male and paratype female, W.A., Millstream, 23.vii.1958, R. P. McMillan in WAM, Perth. Two ♀♀ paratypes (one teneral without dorsal pigmentation), W.A., Drysdale River, 18-21.viii.1975, (14°39'S, 126°57'E), I. F. B. Common & M. S. Upton. One ♀ paratype, W.A., Drysdale River, 3-8.vii.1975, (15°02'S, 126°55'E), I.F.B.C. and M.S.U. ANIC, Canberra.

Distribution: W.A.

Male 7.0 long, width 4.6. Females 7.8 long, width 4.5-4.9.

Colour: Head yellowish-brown, medianly a longitudinal stripe of contiguous brown spots, constricted midway along length. Pronotum medianly shining, lateral margins dull yellowish-brown. From anterior margin two broad brown bands almost reaching posterior 1/3; anteriorly with two secondary groups of brown punctures directed towards middle of disc. Pronotum lightly striated with inverted brown "V" shaped pattern between secondary groups of brown sculpturing; much of disc covered with shallow pits; middle of posterior margin with short brown bar directed cephalad. Scutellum pale with broad brown band from base to apex. Embolium basally yellowish-brown apically dark brown outlined in pale yellow. Clavus and corium dark brown with confused pattern of yellowish-brown lines. Membrane dark brown with small yellowish nodules. Connexiva anteriorly yellowish, posteriorly dark brown to black. Underside shining pale yellow other than dark brown embolium. Ventral latero-tergites basally dark brown. Legs pale yellow.

Structure: Posterior interocular space greater than anterior width. Inner lateral eye margins more or less straight, converging anteriorly. Greatest width of head 3× median head length and just over half of pronotum. Pronotal humeral width about 2.5× median length, lateral margins slightly convex; humeral angles directed caudad. Scutellum punctate, just under 2× broader than long. Emboliar fracture anteriorly prominent, posteriorly obsolete. Clavus and corium not differentiated; membrane continuous with corium and coriaceous (Fig. 41). Postero-lateral angle of sixth connexiva slightly produced in female; third-sixth postero-lateral angles of male connexiva forming an approximate 90° angle. Labrum about 1.5× broader than long. Mesosternal ridge elevated posteriorly,

crest covered with shining yellow hairs. Mesosternal carina vestigial. Sternites covered in thick shining golden pubescence. Ventral latero-tergites narrow (Fig. 40). Female sixth sternite 2× longer than fifth and 1.25× longer than seventh. Operculum (Fig. 54). Seventh parasternite with vestigial depression. Male fifth sternite (Fig. 29). Front leg (Fig. 55). Male genitalia (Figs 42–49), capsule sclerotised, not membranous apically, parameres long.

Naucoris subaureus is easily recognised by the thick golden pubescence covering the median sternites, produced pronotal angles and striking pattern on the clavus and corium.

Comments on distribution and biology of Australian Naucoris

Within Australia there are two species pairs *N. australicus/congrex* and *N. subopacus/rhizomatus*. The fifth species *N. subaureus* is anomalous.

Naucoris australicus/congrex: These are superficially similar in size and general coloration and in having an "easterly" distribution. There are insufficient data to comment any further on *N. australicus*. The most northerly record of *N. congrex* is Mareeba, Atherton Tableland, Qld. Its occurrence so far north may be as a result of a "climatic" anomaly caused by the "high" plateau with a more temperate climate compared with the tropical climate of the surrounding areas. *N. congrex* is common in Tas. and data suggest that at the southern end of the range, it is normally univoltine. Occasionally a partial second generation may overwinter in the immature stages. Data based on samples collected 1972–1973 from Tas. (small lake, Pawleena; Coal River 4 miles north of Richmond; small lake, upper reaches Sorell River and Blackmans Lagoon) tend to support this hypothesis. Mature adults are present from March–October, but by then numbers appear to be low. Pairing and oviposition presumably take place in August–September; by November, 3rd instar nymphs are present. Immature stages continue to be present until February. Teneral adults start appearing in January or earlier (no data are available for December). By March adults are mature and the immature stages are not usually present. Immatures were collected in May from Blackmans Lagoon possibly representing an overwintering population of immature *N. congrex*.

In Tas. *N. congrex* has a low index species diversity; for example if *N. congrex* is common it out competes other waterbugs. Of some 64 habitats sampled *N. congrex* was found in ten, eight of which have five other species of aquatic and semi-aquatic Heteroptera. Greatest diversity was in Blackmans Lagoon (nine species total) which was

sampled quite extensively. On the mainland, *N. congrex* is found most commonly in Vic. This probably is due, in part, to the greater number of freshwater habitats in Vic. compared with S. Aust., and also reflects lack of collecting in N,S.W. In Vic., *N. congrex* was found in nine out of 37 habitats; greatest species diversity was 15, the lowest three; of the latter, *N. congrex* was the commonest species. Immature stages were collected from March–June in Vic. and Qld.

Naucoris subopacus/rhizomatus: These two species are remarkably similar in size, configuration and coloration. Both have a "northerly" distribution extending from N.W. Australia, across the N.T. to Qld near Laura. Most of the habitats sampled by the author in 1979 where *N. subopacus* was found also had *Diplonychus* (Belostomatidae) present. The belostomatid populations were always much greater numerically than those of *N. subopacus*.

Naucoris subaureus: Does not belong to either of the species pairs and is unlike other *Naucoris* species from SE Asia. The Millstream Oasis south of the Great Sandy Desert if noted for its distinctive fauna, especially Odonata (Watson 1981). Data on water-bugs are scanty. The occurrence of *N. subaureus* in the Drysdale River area of NW Australia suggests that the Sandy Desert does not impede the dispersal of water-bugs between the Millstream Oasis and the Kimberley.

Aphelocheirus australicus Usinger
FIGS 62–69

Aphelocheirus australicus Usinger, 1937, pp. 341-342.
Aphelocheirus: Woodward et al., 1970, p. 456 (mentioned only).

Useful diagnostic features are: Head, pronotum, scutellum and most of clavus more or less shining. Corium and embolium dull. Underside appearing smooth and shining.

Body dorso-ventrally compressed. Head longer than broad, antennae long, four-segmented, usually visible from above. Rostrum reaching mid-coxae. Pronotum transverse, lateral margins explanate; median length clearly shorter than median head length; posterior margin roundly emarginate in front of scutellum. Embolium basally broad, tapering apically along margin of corium. Membrane distinct from corium. Connexivum broadly exposed. (Usinger's figure shows first visible connexival segment infuscated.) Specimens from N. Qld have this segment pale yellow, not broadly infuscated, as are remainder (Fig. 62). Femora of all legs dorso-ventrally flattened (Figs 63, 64). Fore and mid legs alike. Male genitalia (Figs 65-69); within capsule, pair of processes attached to lateral plates; distally processes heavily sclerotised with dark brown spines apically (Fig. 66). These
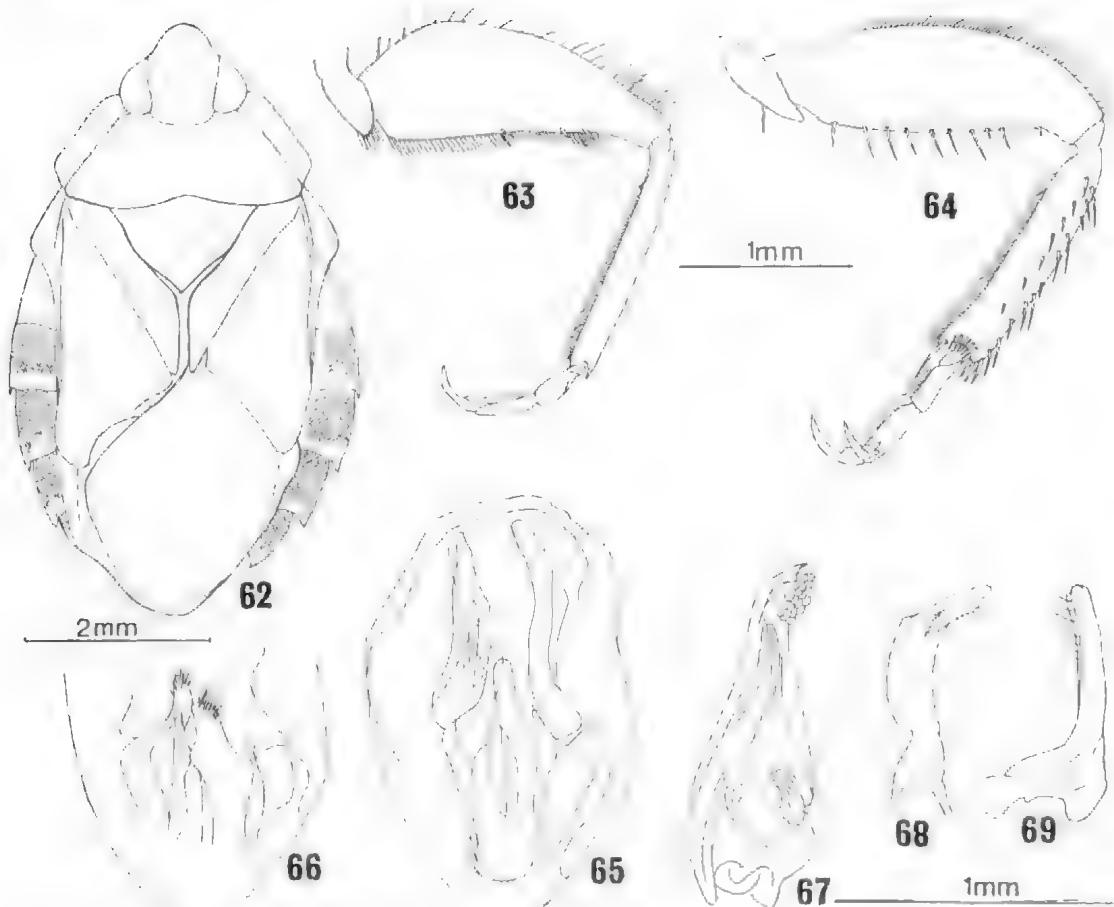
Figs 62–69. *Aphelocheirus australicus* Usinger, male, Cape York, Lockerbie, Qld. 62, dorsum; 63, fore leg; 64, mid leg; 65, genital capsule; 66, detail of spinose processes on lateral plates; 67, aedeagus; 68, 69, left and right parameres

structures not found in *Naucoris*. Aedeagus more robust (Fig. 67). Parameres elongate, symmetrical with long spines distally (Figs 68, 69).

Hoberlandt & Štys (1979) comment on the "apparent" venation of the membrane of some Apehlocheirines. The female from "Captain Billy Creek" appears to have vestigial venation. By examination under a strong light, it is possible to detect slight folds in the texture of the membrane, the folds forming two irregular cells with unconnected brachial pattern. A male from Lockerbie does not have a cellular pattern but more a confused anastomosing system. Originally described from Cairns, Qld the holotype female is said to be in the California Academy of Sciences.

Material examined: (all macropterous), Qld, 142°45'E, 11°40'S, Dividing Range, 15 km west of Captain Billy Creek, Cape York Peninsula, 5-12.ii.1976, G. B. Monteith; Upper Qld, Lockerbie area, Cape York, 13-27.iv.1973, G.B.M. QM, Brisbane.

Aphelocheirus is normally thought to be restricted to well-oxygenated water; the bugs are found crawling about beneath rocks and stones. Typical *Aphelocheirus* habitats are the Boulders at Babinda near Cairns where the creek flows very rapidly over and under granitic boulders. The habitats in Cape York are described by Monteith as swampy with sluggish streams. All Cape York material was collected at light (T. E. Woodward *in litt.* 4.iii.1977). Hoberlandt & Štys (1979) commented on flight in the Aphelocheirinae and all the known material of their new taxa were taken at light.

In the Palaearctic region the presence of *Aphelocheirus* is taken as a reliable indicator of water purity. The species *A. aestivalis* has an efficient plastron allowing gas exchange to take place without the bug having to surface, in contrast to *Naucoris*. The Cairns habitat tends to suggest

that Australian *Aphelocheirus* has a similar plastron respiration system. However, the presence of the species in Cape York occurring in swamp sluggish creeks need not be considered unusual as Thorpe & Crisp (1947) list a wide variety of habitats where *Aphelocheirus aestivalis* (F.) has been found in Europe. Within the Palaearctic region, *Aphelocheirus* is dimorphic but it is not known if it is so in Australia.

Acknowledgments

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COASTAL SEDIMENTARY FACIES AND FORAMINIFERAL BIOFACIES OF THE ST KILDA FORMATION AT PORT GAWLER, SOUTH AUSTRALIA

BY J. H. CANN & V. A. GOSTIN

Summary

The St Kilda Formation, within Gulf St Vincent and surrounding coast lands is redefined to include all Holocene sediments deposited under the influence of marine processes. Upper surfaces of the formation are not confined, but rather may be surfaces of active sedimentation.

COASTAL SEDIMENTARY FACIES AND FORAMINIFERAL BIOFACIES OF THE ST KILDA FORMATION AT PORT GAWLER, SOUTH AUSTRALIA

by J. H. Cann* & V. A. Gostin†

Summary

Cann, J. H. & Gostin, V. A. (1985) Coastal sedimentary facies and foraminiferal biofacies of the St Kilda Formation at Port Gawler, South Australia. *Trans. R. Soc. S. Aust.* **109**(4), 121-142, 29 November, 1985.

The St Kilda Formation, within Gulf St Vincent and surrounding coastal lands is redefined to include all Holocene sediments deposited under the influence of marine processes. Upper surfaces of the formation are not confined, but rather may be surfaces of active sedimentation.

Port Gawler is an area where marginal marine sediments are accumulating under the baffling, trapping and binding actions of seagrasses, cyanobacterial mats, mangroves, samphires and saltbush. These plant communities occur in essentially discrete zones, successively adjacent and parallel to the tidal shore lines. Their influence causes progradation and aggradation of bioclastic carbonate quartz sands and muds. Bivalves, gastropods and foraminifera are abundant and contribute significantly to the carbonate component of sediment. Distribution of molluscs is closely related to plant communities, sediment type and period of tidal inundation. Thus a series of laterally adjacent sedimentary facies are recognised to be associated with the following sub-environments: subtidal and intertidal seagrass meadows; mangrove woodland; tidal distributaries; cyanobacterial mats of the inner sand flat; high tide beach; supratidal lagoons or sabkhas, dunes and storm ridges; the estuary and associated backwaters of the Gawler River.

Foraminiferal biofacies, based on selected sieved fractions of dense-liquid flotation concentrates are established for the various sedimentary environments. In two vibrocores, down-hole assemblages of foraminifera are similar to those of modern Port Gawler environments. Palaeoenvironmental interpretation of the cores, based on both lithology and assemblages of foraminifera, shows that the earliest sediments of the Holocene transgression were essentially samphire muds and shelly storm debris. Later sedimentation, after sea level stabilised, occurred through processes of progradation and aggradation, inextricably related to communities of seagrasses, mangroves, cyanobacterial mats and samphires.

Key Words: Port Gawler, Gulf St Vincent, Holocene, St Kilda Formation, foraminifera, molluscs, coastal sediments.

Introduction

The eastern coast of northern Gulf St Vincent is normally subject to a low energy wave regime. This fact, together with northward longshore drift, ensures that it is an area of active sedimentation. Low topographic relief of the coastal areas, and extensively developed sand and mud flats, result in broad intertidal areas. High tides associated with storm surges cause inundation of normally supratidal environments.

From seaward of the low tide shore line to the supratidal areas there is a pronounced zonation of plant communities. These range from subtidal and intertidal seagrass meadows, through mangrove woodlands and cyanobacterial mats, to supratidal samphires and saltbush. In various ways the plants baffle, trap and bind sediment causing aggradation and progradation of the sand flats. Molluscs and foraminifera are abundant and their shells and tests contribute significantly to the accumulating sediment. Also, species of these fauna are

distinctively distributed through the zoned plant communities and there are several consistent plant/animal associations.

This paper documents relationships between plant communities and sedimentary processes at Port Gawler, northern Gulf St Vincent. A method of foraminiferal analysis, involving dense-liquid flotation concentrates, and selected sieved fractions, is described and used to establish foraminiferal biofacies for the various sedimentary environments. These data are used in palaeoenvironmental analysis of two cores of Holocene sediment.

For Port Gawler and surrounding coastal areas, it is proposed that all Holocene sediments, deposited under marine influence, rightly belong to the St Kilda Formation. This usage includes those sediments, subtidal, intertidal and supratidal, forming at present.

The St Kilda Formation

In South Australia considerable confusion has prevailed in the interpretation of the St Kilda Formation since Firman (1966) first proposed this and other Holocene stratigraphic units.

On the one hand, Firman (1966) defined the formation as "various lithologies delimited for

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mapping purposes by the low lying swampy tract which extends a mile or more inland near St Kilda and elsewhere along the modern coast." That is, he included the modern supratidal samphire sediments as a facies of the St Kilda Formation. This interpretation was followed by Thompson (1969) who referred "light-grey shelly stranded beach ridge deposits and shelly silts and sand overlain in places by modern intertidal and swamp deposits" to the Holocene St Kilda Formation, and showed these sediments to be distributed along the eastern coast of Gulf St Vincent, extending inland about 5 km.

On the other hand, Firman's definition related sediments of the St Kilda Formation to the "raised sea-bed" of Tate (1879, p. 69) and to the marine sands and clays of the Osborne high sea level (Aitchison, Sprigg & Cochrane 1954). Daily *et al.* (1976) elaborated on this interpretation, clearly relating the formation to "a high stand of the Flandrian sea when shelly sand . . . was deposited." Their evidence for a supposed higher Holocene sea level, about 1.5 metres above modern sea level, consisted largely of stranded beach ridges, and they cite dates of 3 800 + 500 and 1 120 + 75 radiocarbon years B.P. respectively for the base and top of the St Kilda Formation. By implication, marginal marine sediments younger than 1 120 ± 75 radiocarbon years B.P. were therefore excluded from the St Kilda Formation. This interpretation was recently followed by Totell (1983) in the Draft Management Plan for the Port Gawler Conservation Park. A figure illustrating bore hole stratigraphy, after Lindsay (1965)[1], refers to 1.5 metres of modern sediment (black sandy clay and mud with plant fibres) overlying 4.6 metres of St Kilda Formation (sandy clay with shell fragments).

Thus ambiguity persists in the use of the formation name. One interpretation includes the modern marginal marine sediments together with those of earlier Holocene age. The other, based on the premise of a higher than present stand of the Holocene sea, excludes those sediments younger than 1 120 ± 75 radiocarbon years B.P.

Belperio *et al.* (1983) reviewed evidence relating to Holocene sea levels in South Australia and concluded that there was little evidence to support the notion of higher Holocene sea levels in the Adelaide region. They emphasised the importance of processes of coastal progradation and intertidal and supratidal deposition, and considered shell ridges to rate poorly as evidence for higher sea levels. In this paper we follow Belperio *et al.* (1983).

Consequently we see no reason to invoke any recent lowering of sea level and we are unable to stratigraphically differentiate the marine Holocene sediments. Within Gulf St Vincent and surrounding coastal lands we therefore recognise the St Kilda Formation to include all Holocene sediments deposited under the influence of marine processes, including estuarine deposits, coastal dunes and storm ridges. As such, the St Kilda Formation is a readily mappable unit, consisting internally of various sedimentary facies, deposited under a variety of marine processes. Sediments of the Lipson Formation and Semaphore Sand (Firman 1966) may thus be interpreted as facies of the St Kilda Formation.

The base of the St Kilda Formation is well defined. The unit disconformably overlies Pleistocene sediments of the marine Glanville Formation (Firman 1966; Cann 1978) and the alluvial Pooraka Formation (Firman 1966). Earliest deposition in the Adelaide region has been dated at 6 440 ± 90 radiocarbon years B.P. (Belperio *et al.* 1983). In our present usage, upper surfaces of the St Kilda Formation are not confined, but rather may be surfaces of active sedimentation. The Germein Bay Formation of Spencer Gulf is equivalent (Hails *et al.* 1984).

The study area

The study area is situated about 12 km northwest of St Kilda, the type location for the St Kilda Formation (Fig. 1). The area is almost topographically flat with samphire swampland to the east, passing through mangrove woodland and open sandflats to seagrass meadows westwards. Immediately eastwards are salt concentration evaporation ponds, the most northerly of a system leading to salt extraction at Dry Creek. The area includes the estuary of the Gawler River, site of the now disused Port Gawler (Lisbon Wharf, Fig. 2).

Gawler River has its source in the Para Fault Block, approximately 40 km east of Port Gawler. It is an intermittent stream, generally confined to a narrow, meandering channel as it traverses the northern Adelaide Plain. At times of heavy rainfall, fine grained clastic sediments are transported into the estuary, from where they are redistributed throughout the study area by coastal marine processes.

The region of South Australia which includes Port Gawler experiences a pronounced Mediterranean type of climate. Summers are mostly hot and dry with maximum temperatures greater than 40°C not uncommon. Winters are generally mild, night temperatures rarely falling to 0°C. Average annual rainfall of 420 mm at Port Gawler occurs mostly

[1]Lindsay, J. M. (1965) Stratigraphy and micropalaeontology of three deep bores, hundred of Port Gawler. S. Aust. Dept Mines Rept Book 65/51 (unpublished).
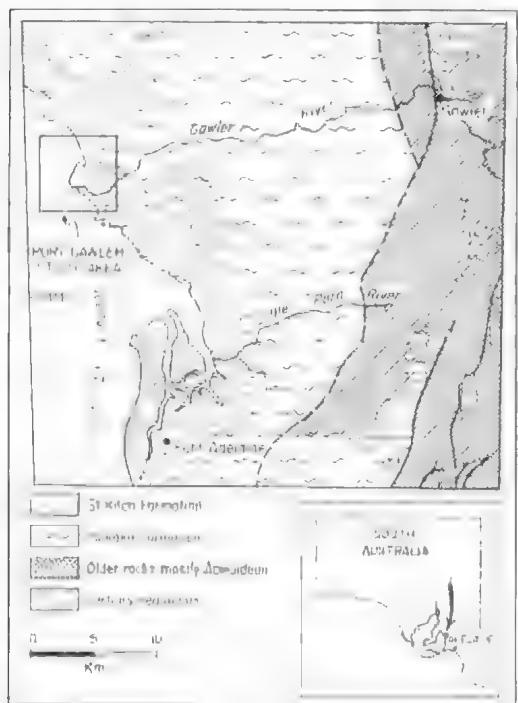
Fig. 1. Location map showing surface distribution of the Holocene St Kilda and Pooraka Formations, as used in this paper, and other simplified geology.

Fig. 2. Ruins of Lisbon Wharf, Port Gawler. This facility was historically important for the export of grain and wool in the years 1839 to 1914. (Toteff et al. 1983).

during the cooler months, though occasional summer thunder storms produce heavy falls of rain. Evaporation has been estimated at 1800 mm annually (Toteff 1983).

The areas influenced by normal tidal changes of sea level at Port Gawler are extensive. The gradient seawards from the samphire salt marsh is almost imperceptible and maximum astronomical tidal variations are about 2.5 m. At maximum high tide,

sea water covers the sand flats and floor of the mangrove woodland, and flows through tidal distributaries to the samphire marshland beyond. At minimum low tide, the sea retreats to the extreme seaward margin of the sand flat.

Superimposed on normal tidal fluctuations are the longer term effects of surges with periods of 1 to 20 days, and thought to relate to the passage of weather systems (Provis & Radok 1979). Kelly (1984) has reported storm surge sea level fluctuations of 0.5 m along the southern Australian coast. When a storm surge coincides with a spring high tide, unusually high tides result. Abnormally large volumes of water move across the sand flats and through the mangrove tidal creeks, flooding the samphire marshland and adjacent (normally) supratidal areas. When these conditions are further accompanied by local winter storm activity, with strong south westerly winds, sea water is driven even more deeply into the coastal environments. The combined effects of tidal currents and storm waves in these circumstances can cause considerable erosion and redistribution of sediment.

The wave regime of Gulf St Vincent has been discussed briefly by Bye (1976) and, more comprehensively and with particular reference to the Adelaide beaches, by Wynne et al. (1984). The configuration of the Gulf is such that, along the eastern coast, prevailing south westerly winds generate waves of maximum fetch south of Adelaide. Adelaide beaches are subject to a lower wave energy regime which generates significant alongshore transport of sand northwards towards the study area. Except under storm conditions, wave energy from Port Gawler to the top of the Gulf is very low.

Vegetation

The role of vegetation in determining the nature and distribution of sediments at Port Gawler is fundamental and is discussed in greater detail below. In general the various cyanobacteria, algae, seagrasses, mangroves and other plants perform two significant functions. Firstly, they are the autotrophs in food chains leading to organisms which secrete shells or tests of calcium carbonate. These shells and tests, either intact or comminuted, ultimately become part of the sediment. Secondly, in a variety of ways, they actually cause deposition of sediment, trapping grains of calcium carbonate, quartz and other mineral matter.

Posidonia australis, the broad leaf species, is a seagrass commonly known as "tape-weed". It is common in Gulf St Vincent, living from low tide level to depths of about 10 m. Posidonia has tough, roughly textured leaves that host a variety of

epiphytes (Womersley 1956). The flat ventral surface of the foraminifer *Nubecularia lucifuga*, abundant at Port Gawler, often shows striae-like imprints of these leaves. Womersley & Thomas (1976) considered that few animals feed directly on the *Posidonia* leaves. The rhizome/root system and leaf sheaths of this plant are dense, fibrous and resistant to organic decomposition. *Posidonia australis* leaves can survive only brief periods of emergence at low tides. At Port Gawler it grows in the outermost areas of the sand flat in the lower intertidal zone, and seawards.

Zostera muelleri is another seagrass, of narrower leaf, commonly referred to as "eel-grass". Like *Posidonia*, this plant has a rhizome/root system and hosts epiphytic algae and animals (Womersley & Thomas 1976). At Port Gawler, *Zostera*, together with species of *Heterozostera*, *Lepilaena* and *Ruppia* (as described by Robertson 1984), forms extensive, dense, seagrass meadows seaward of the bare sand flat, and seaward of, and adjacent to the mangrove woodland. These seagrasses can survive longer periods of emergence at low tide.

Avicennia australis var. *resinifera* is the only species of mangrove found in South Australia and occurs at Port Gawler in both mature woodland and as younger colonising plants (Butler *et al.* 1977; Harbison 1981; Burton 1982a; 1982b; Talbot 1982; Toleff 1983). Tidal distributaries form a dendritic pattern through the mature woodland. Sea water flushes accumulated salt from around the mangrove roots (Butler *et al.* 1977) and distributes algal, seagrass and other organic flotsam. Much of this organic debris probably provides nutrient for the mangroves and is a source of food for a variety of gastropods. Mangroves are confined in their distribution seawards by the need for their vertically protruding pneumatophores to be periodically exposed to the air, and landwards by the need for regular flushing of accumulated salt from the roots by sea water at high tide (Chapman 1975). Juvenile mangroves are colonising the *Zostera* meadow seawards of the bare sand flat at Port Gawler. During the past decade we have observed their establishment progressively southwards over several hundred metres from the older trees.

Mats of cyanobacteria (= blue-green algae) colonise both the floor of the mangrove woodland and the mid-tide bare sand flat. They are dull green in colour and slippery. Mats are constructed at the sediment/water interface by one or more species of cyanobacteria and may also contain a variety of true bacteria and other algae. Cyanobacterial mats are among the most productive of aquatic photosynthetic systems (Bauld 1981). At Port Gawler the mats are apparently grazed by a variety of gastropods. Their distribution on the open sand flat appears delimited by grazing gastropods seawards, and by the infrequency and short duration of high tidal inundation of the sediments closest to the beach.

Halosarcia halocnemoides and *Sarcocornia quinqueflora* are dominant plants of the samphire salt marsh community. These are low-growing, fleshy plants which have considerable salt tolerance and occupy the zone immediately landwards of the mangroves.

Sedimentation at Port Gawler

1. Posidonia-Pinna *Facies/Zone*

At low tide it is possible to observe the seaward margin of the sand flat. *Posidonia australis* grows in patches 20–30 m^2 in area. *Pinna bicolor* (= *P. dolabrata* and *Subitopinna virgata*) [Butler & Brewster 1979], known locally as "razor fish", is conspicuously abundant, growing in among the seagrass. The sediment is coarse, poorly sorted, shelly sand. Carbonate content is greater than 90%, much coming from lime secreting organisms hosted by the *Posidonia*. Foraminifera are particularly plentiful among the smaller grains; among the larger shelly organisms, *P. bicolor* may grow to a length of 20 cm in a single year (Butler & Brewster 1979).

Patches of *Posidonia* on the outermost areas can be observed in various stages of burial by the mobile sand (Fig. 3A). The baffling action of the seagrass apparently traps the sediment. Studies in the Bahamas by Scoffin (1970) and Neumann *et al.* (1970) show that seagrasses can reduce water velocity from 30 cm sec^{-1} (sufficient to transport loose sand grains along the bare sea floor) down to zero at the sediment/water interface. As the sediment accumulates, *Posidonia* grows upwards, but is constrained by its inability to survive low tide emergence and it ultimately dies. Large areas of the remains of recently dead seagrass together with numerous empty *Pinna* shells, valves gaping and in life position, may be observed immediately landwards of the present day low water shore line (Fig. 3B).

Carbonate sand is therefore accumulating up to low tide level, causing the outer margin of the sand flat to prograde seawards. In some areas, after death of *Posidonia*, the uppermost sediment remains bare of vegetation and consequently subject to tidal and storm wave transport. Such surfaces become scoured, channelled and rippled as the shelly sand is redistributed according to energy conditions. Mostly, however, the sediment mass remains essentially coherent, reinforced by seagrass filmy,
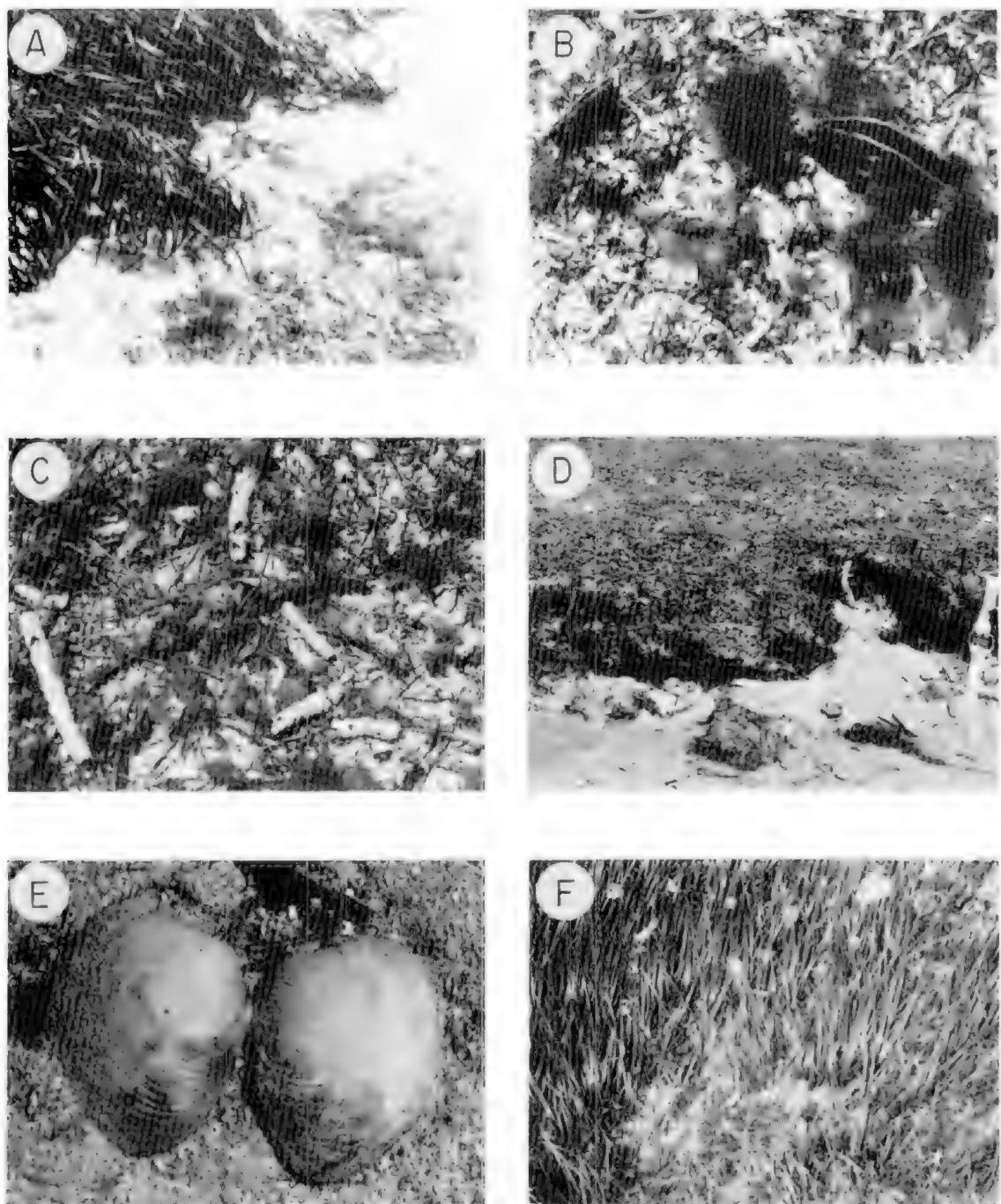
Fig. 3A. Patch of partly buried, living *Posidonia*, adjacent to remains of recently dead *Posidonia*; outermost sandflat. B. Dead *Posidonia* remains with dead *Pinna*, valves gaping, in life position; outermost sandflat. C. Remains of agglutinated worm tubes, approximately 2 cm diameter. These tubes are constructed of carbonate sand grains and orientated vertically in the uppermost 0.3–0.5 m of sediment. Scouring by waves or tidal currents cause them to fragment. Outermost sandflat. D. Dense, fibrous remains of dead seagrass (*Zostera*) after death and loss of foliage; section exposed in tidal channel; wrist watch for scale is 22 cm long. E. Recently dead *Katelysia* (×?), valves attached, convex upwards; bare surface adjacent to *Zostera*. F. *Zostera* in the seagrass meadow.

by large vertically oriented *Pinna* shells, and by numerous worm tubes of agglutinated shell grit. Algal growth on the substrate helps to minimise scouring by tidal currents and storm waves. We have observed considerable progradation of the sand flat during the past decade.

2. Zostera-Katelysia *Facies/Zone*

In the mid tidal area, the sand flat is colonized by a seagrass meadow, consisting of several species, in which *Zostera muelleri* predominates (Fig. 3F). The dominant bivalve mollusc is *Katelysia* sp. (Fig. 2E). *K. scalarina* has been recorded from Port Gawler by Toteff (1983), but three species of *Katelysia* may be present (Ludbrook 1984). Disarticulated valves of *Katelysia* sp. have been widely redistributed throughout the study area.

Like *Posidonia*, *Zostera* baffles and traps sediment. The mid tidal area is less influenced by wave action and tidal currents, so grain size is correspondingly smaller and there is a significant mud component. Sediment is rich in organic matter, supporting bacterial reduction of sulphate ions from sea water. Below the sediment/water interface it is black and has a strong sulphide odour (Fig. 4A). Burrowing by small crabs tends to extend to the underlying, grain supported sand of the *Posidonia-Pinna* facies. Bioturbation tends to, in part, oxidise and homogenise the sediment.

Aggradation of sediment in the *Zostera* meadow continues to a level determined by the period of low tide emergence. Ultimately the plants on the landward side of the meadow are inadequately watered at high tides and they die. On the seaward side, the meadow advances over the old *Posidonia-Pinna* substrate, and the finer sediment facies thus progrades.

3. Mangrove *Facies/Zone*

At Port Gawler we have observed the colonising advance of juvenile mangroves, *Avicennia australis* var. *resinifera*, across portion of the *Zostera* meadow (Fig. 4B).

It is evident that the finer, muddier and organic-rich sediment trapped by this seagrass is an ideal substrate for mangrove colonisation. The mangroves therefore represent a third major stage of plant/sediment succession.

Young mangrove trees quickly establish a lateral root system, each root bearing a series of vertically protruding pneumatophores. Each plant is surrounded by radiating rows of these spike-like structures, 20-30 cm high. For a time both mangroves and seagrass co-exist, but as the density of pneumatophores increases, so too does the amount of organic flotsam that is trapped by, and adheres to, these subaerial roots. The *Zostera* thus dies under a blanket of accumulating marine compost.

Fine sediment continues to accumulate in this facies as the mangrove woodland grows to maturity. Algal and seagrass debris bring epiphytic carbonate organisms which remain as grains in the sediment. Thus aggradation proceeds to levels where the floor of the mature mangrove woodland (Fig. 4C) is inundated for only brief intervals during high tides. The sediment/water interface is then colonised and stabilised by a cyanobacterial mat which introduces new depositional processes (discussed below). The substrate is intensively burrowed by the small mud crab, *Helice haswellianus*, facilitating sea water permeability and aeration. The mangrove sediment thus becomes oxidised and homogenised.

Throughout this episode of deposition a dendritic pattern of tidal distributaries develops and is maintained.

4. Tidal distributary *facies*

Tidal water movement is concentrated along distributary channels which are best developed within the mangrove woodland. As a consequence of the dendritic pattern of channels, current speeds are variable and sediment type varies accordingly. Major, shallow channels have coarse, shelly debris, rich in valves of *Katelysia* and *Anapella* (Fig. 4F), disarticulated and convex upwards. Deeper backwater channels have a high component of black sulphide mud.

A major component of the shelly fauna within the mangrove tidal distributaries is the small turriform gastropod *Batillaria (Zeacumantus) diemenensis* (Ludbrook 1984). Where channels meet the open sand flat, shells of this gastropod are numerous and current aligned (Fig. 4E). They have been widely redistributed throughout the study area.

5. Cyanobacterial Mat-Sand Flat *Facies/Zone*

Bauld (1981) has illustrated the ability of cyanobacterial mats to fix sediment in Spencer Gulf. He describes how entangled trichomes of *Microcoleus* sp., and their enveloping mucilaginous sheaths, trap and bind sediment in a thin, coherent layer. In addition, photosynthesis at the mat surface removes carbon dioxide from sea water, increasing pH and favouring precipitation of calcium carbonate.
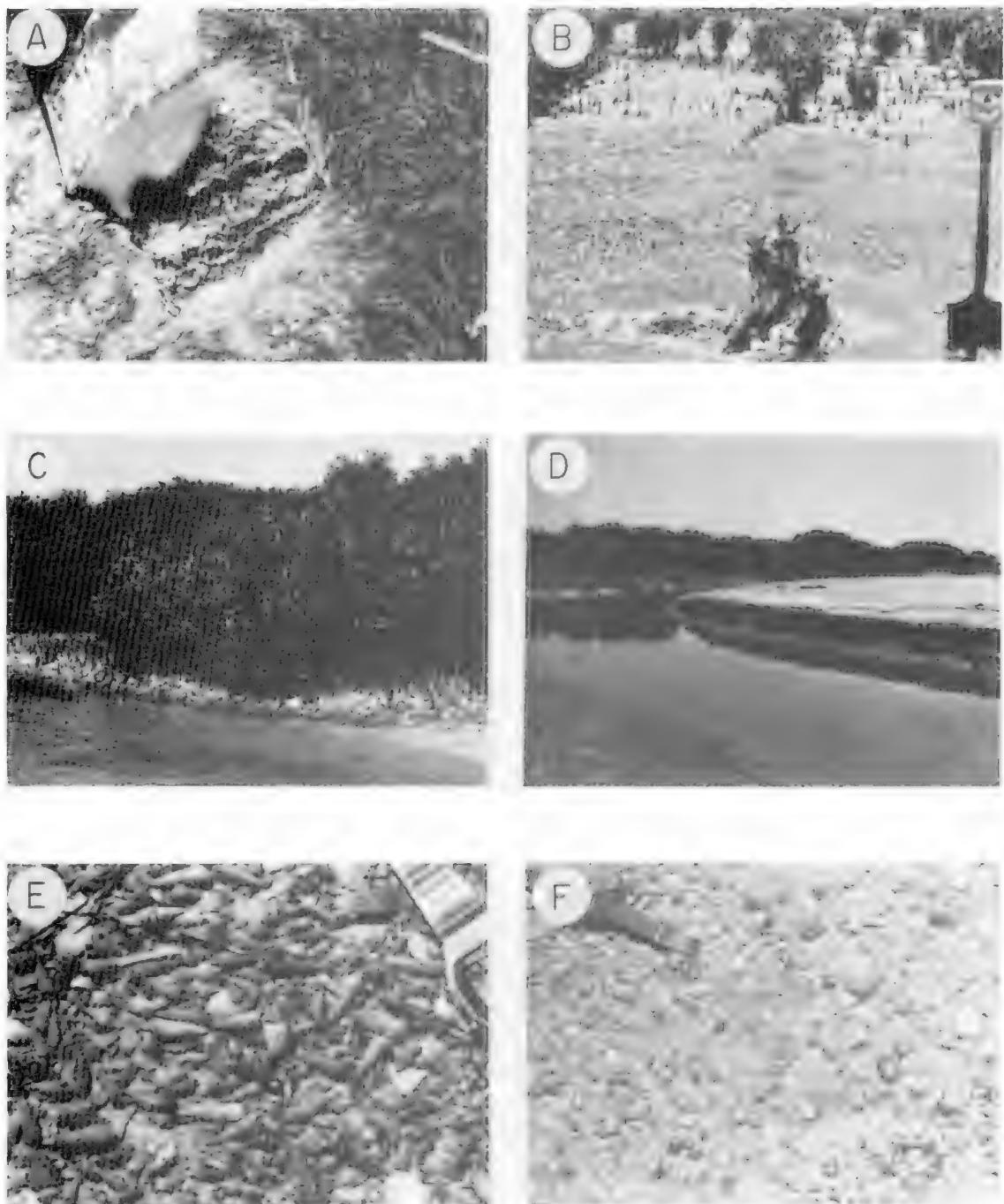
Fig. 4A. Sediment of the *Zostera* meadow, shelly sand, rich in sulphide and mud. B. Juvenile colonizing mangroves in the *Zostera* meadow; algal and other plant debris adheres to pneumatophores and smaller plants. C. Mature mangrove trees adjacent to a tidal distributary. D. Tidal distributary with mature mangrove woodland, left, and inner sandflat with cyanobacterial mat, right. E. Gastropod shells, mostly *Batillaria*, are a major component of the sediment in the mangrove tidal distributary (Figs. 4C D). F. Sediment of tidal distributary which separates the *Zostera* meadow from the inner sandflat. Bivalves, mostly *Katelysia* and *Anapella* are disarticulated and convex upwards.

Cyanobacterial mats cover a large part of the otherwise unvegetated sand flat, the floor of the mangrove woodland and some of the supratidal areas. These are therefore sites of sediment aggradation. Sediments bound by cyanobacterial mats are known to withstand current velocities up to five times higher than those required to erode mat-free sediment (Neumann *et al*, 1970).

Sections cut through the active mat (Fig. 5C) reveal a thin layer of oxygenated sediment, below which is black, sulphide-rich, laminated, silty sand (Fig. 5D). Anaerobic bacteria, nourished by the organic matter of previous layers of the mat, reduce sea water sulphate ions. Metals, particularly iron, are fixed in this way. Black sediment turns to a pale rust colour on prolonged exposure to the air. Calcium carbonate content may be as high as 70%.

The cyanobacterial mats support a dense population of grazing gastropods, notably *Salinator* sp. On the seaward edge of the bare sand flat, persistent grazing appears to inhibit establishment of cyanobacteria (Fig. 5B). In this area, large numbers of the small bivalve *Anapella* sp., probably *A. cycladea* (Ludbrook 1984), live clustered together immediately below the sand surface (Fig. 5A). Disarticulated valves of *Anapella* are widely redistributed in sediments of the study area.

The bare sand flat is sharply separated from the *Zostera* meadow to the west, and the mangrove woodland to the south (Fig. 4D), by intertidal distributaries. These tidal channels have remained essentially unchanged for the past decade.

6. *Beach facies*

High tide beach sediment at Port Gawler has a calcium carbonate content of about 80%. The texture is predominantly sandy, but shells originating in all of the other facies occur as constituents. Wide variation in grain size, from shell gravel to fine sand, may be related to variable wave energy, which is a function of water depth and wind strength. Sections cut through the beach reveal horizontal to gently tilted, well-sorted laminae, and, rarely, higher angle cross beds.

Flotsam seagrass debris appears to significantly assist stabilization of beach sediment to seaward, while saltbush and other plants are established in, and fix, the upper beach sands (Fig. 5E). The high tide beach is therefore a mass of accumulating sediment, prograding seawards across the inner sand flat.

7. *Dune facies*

Windblown carbonate sands occur some 50-100 m inland of the beach. This area has been considerably modified by human activity, but the low dune forms, stabilized by saltbush and other vegetation, are clearly identifiable. The sediment is well sorted and consists of fine broken shell and entire small gastropods and foraminifera. Sections cut through the dunes reveal coarser, underlying sediments.

8. *Storm ridge facies*

Storm ridges are formed at times of extremely high tides and local storm activity. Shelly material is driven shorewards under these conditions, and may pile up in a ridge of coarse, poorly sorted shell debris, somewhat paralleling the shore line, but seawards of the beach. If the ridge is continuous, that part of the sand flat between the newly formed storm ridge and the pre-existing beach is isolated from further wave action. A new beach facies is established on the seaward side of the storm ridge, and a new dune facies to landwards.

At northern Port Gawler, extensive storm ridges once existed in the area between the salt evaporation pans and the present high tide beach and dune facies. Shell-grit mining has effectively removed most of this sediment, the location of the ridges now being marked by a number of parallel, elongate, shallow depressions.

Immediately south of the Gawler River, a storm ridge some 1.5 km long and up to 2 m high lies within the mangrove woodland (Fig. 6). It is situated several hundred metres landwards of, and parallel to, the seaward margin of the mangroves. The seaward side of the ridge is straight and steep, suggesting the form of a stranded beach (Ioteff 1983). On this surface Harbison (pers. comm.) has observed numerous large, square-cut pieces of timber, similar to those used in the construction of early South Australian jetties. These items of driftwood were evidently emplaced at the time of, or shortly following, formation of the storm ridge.

Along the coastal plain, north of Port Gawler, numerous more or less parallel storm ridges may be observed.

9. *Supratidal lagoon facies*

Areas of sand flats that have been isolated from open marine influence may still receive sea water via tidal distributaries. Alternatively, water may be supplied by seasonal heavy rain or rising ground water. On the floors of these supratidal lagoons, or sabkhas, cyanobacterial mats often flourish. They maintain low diversity
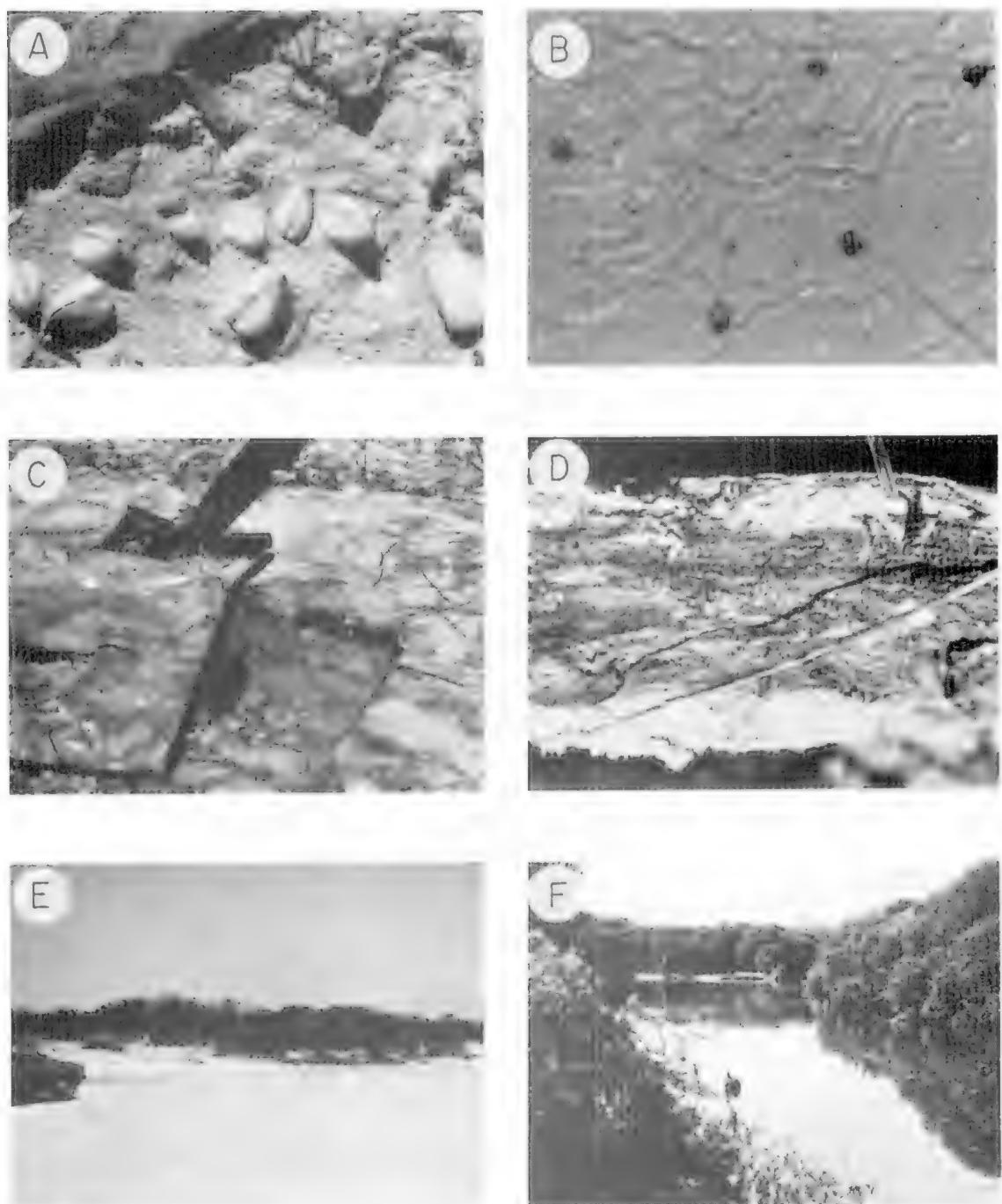
Fig. 5A. Dead *Anapella* bivalves (× 1) in lite position, immediately beneath surface of inner sandflat; section exposed by mangrove tidal distributary. B. Grazing gastropods (× 1) limit growth of the cyanobacterial mat on the seaward areas of the inner sandflat. C. Exposure of sediment beneath the cyanobacterial mat; dark horizon is sulphide rich. D. Detail of sediment slab, Fig 5C. Uppermost laminae are flushed with photosynthetic oxygen; dark lower laminae contain sulphide from bacterial reduction of seawater sulphate. E. Inner sandflat and vegetated high tide beach. F. Mature mangrove trees overhang the Gawler River estuary near the ruins of Lisbon Wharf.
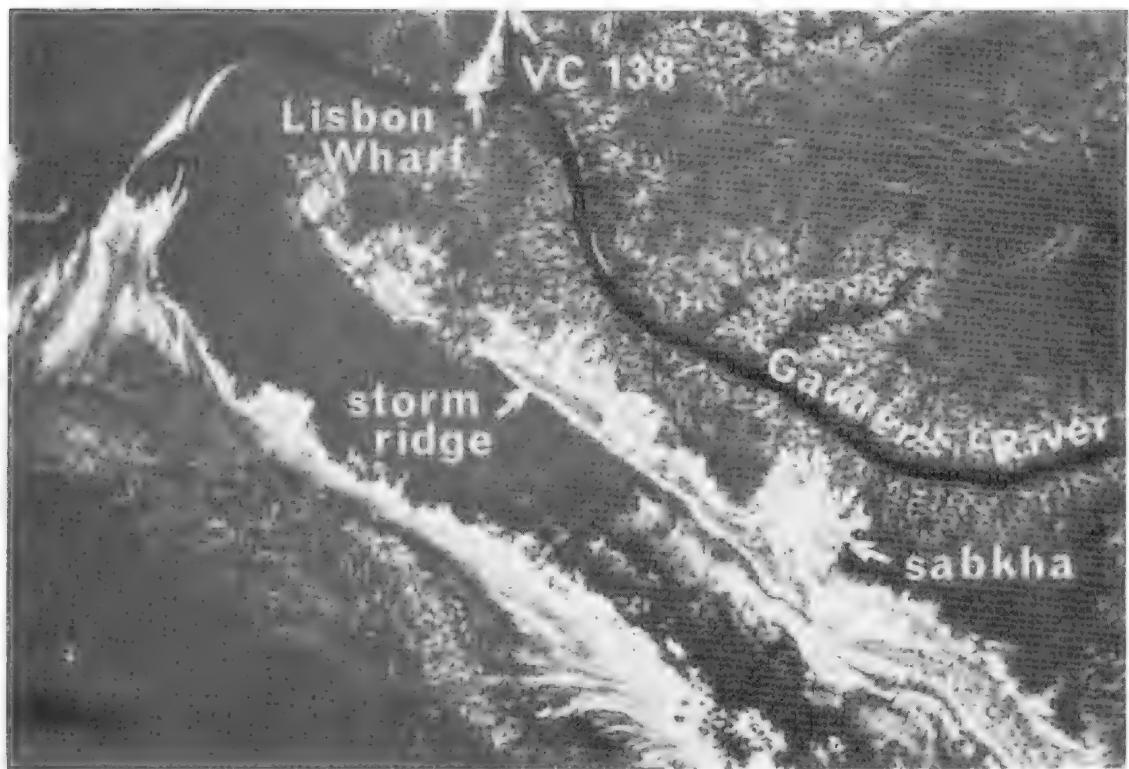
Fig. 6. Aerial photograph of the Gawler River estuary showing the locations of Lisbon Wharf ruins and the site of vibrocore VC 138. A storm ridge and sabkha, south of the estuary, are indicated.

populations of carbonate fixing organisms such as the gastropod *Salinator* sp. and the foraminifer *Elphidium* sp. (Cann & De Deckker 1981). Photosynthesis favours chemical precipitation of calcium carbonate and fine, wind blown sand is trapped by the mats. Gypsum crystals may form during summer evaporation. Samphire plants grow around the margins of these lagoons, where they trap supratidal seagrass flotsam and sediment. In this way they gradually encroach on the area and contribute to its shallow infilling. Supratidal lagoons are therefore sites of active sediment accumulation.

Supratidal lagoon sediment, stabilized by samphire plant growth, occurs adjacent to the storm ridge south of the Gawler River (Fig. 6). To the north of Port Gawler, extensive supratidal lagoon systems occur landwards of the storm ridges. Within the study area this facies has effectively been replaced by salt evaporation ponds.

10. *Estuarine facies*

Large quantities of seagrass, algal and other plant flotsam may be observed on the surface waters of the Gawler River estuary, transported back and forth by the tides. Some of this material becomes entangled in the pneumatophores of the mangroves that overhang the water way (Fig. 5F). Other plant debris accumulates on the muddy bed of the estuary, particularly in backwaters. The resulting sediments are therefore peats and organic rich muds. Sediments of this facies were encountered in vibrocore VC 138 and are discussed further below.

Distribution of the various facies described above is shown by the block diagram Fig. 7.

Foraminiferal biofacies at Port Gawler

Sediment samples were collected, on two approximately straight line transects, from the environments described above. The first transect extended from high tide beach to the edge of the *Posidonia* meadow, approximately along the line of break in block diagram, Fig. 7, the second from a small sabkha within the samphire zone to a mangrove tidal distributary. Samples of approximately 200 ml were taken from the surface to a depth of about 5 cm. Most samples contained appreciable amounts of plant debris.
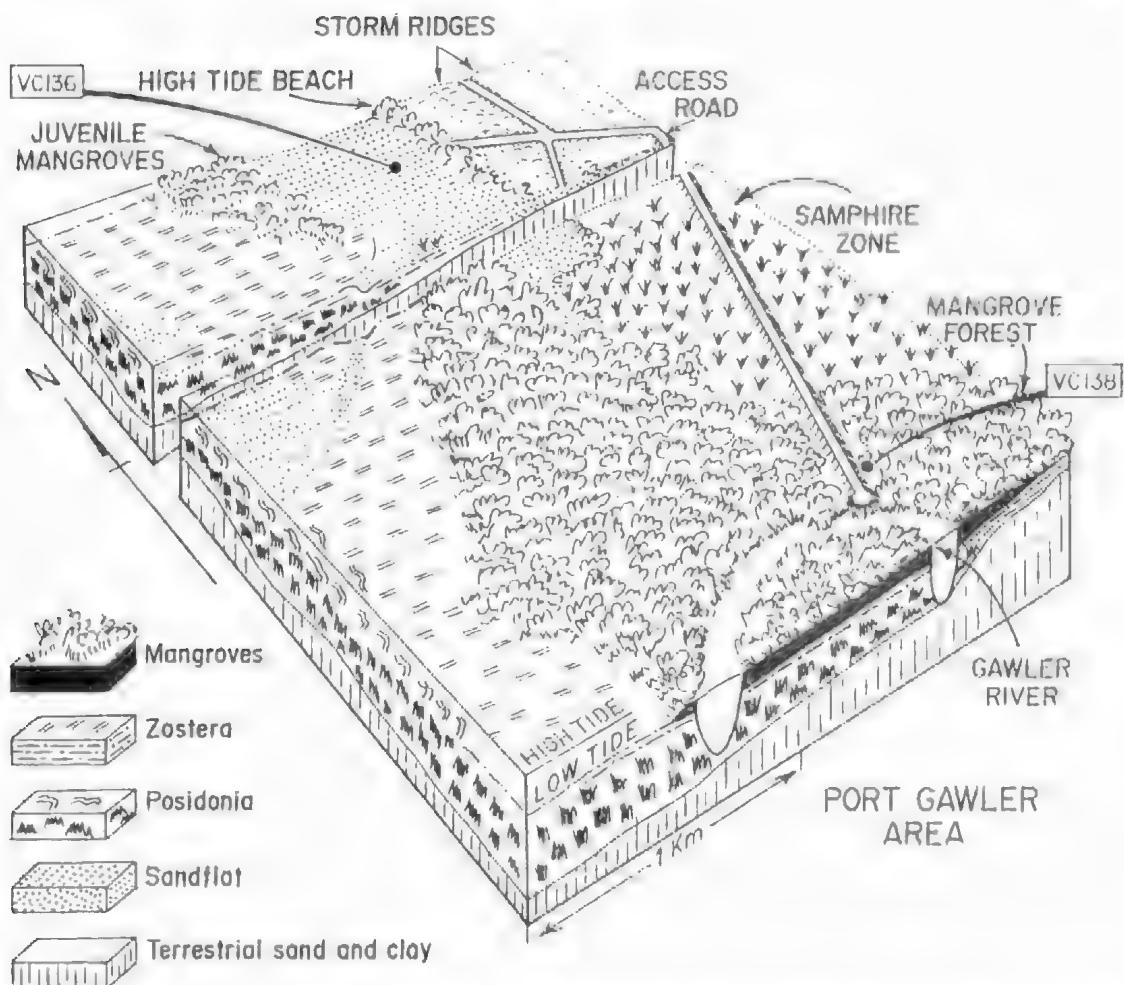
Fig. 7 Schematic block diagram illustrating modern depositional environments and related sedimentary facies of the St Kilda Formation at Port Gawler. Sites of vibrocores VC 136 and VC 138 are indicated

TABLE 1. *Summary of the sedimentary facies of Port Gawler*

Facies	Environment	Sediment type
Posidonia—Pinna	subtidal, outermost sand flat	carbonate quartz shelly sands
Zostera—Katelysia	intertidal sand flat	muddy carbonate quartz sands
Mangrove	intertidal mangrove woodland	carbonate quartz silts, muds and sands with organic debris and cyanobacterial mats
Tidal distributary	throughout the tidal range	channel deposits with convex upwards disarticulated bivalves and current aligned gastropod shells
Cyanobacterial sand flat	high tide inner sand flat	fine carbonate quartz sand bound by cyanobacterial mats
Beach	high tide	shelly carbonate quartz sands and shell gravels
Dune	supratidal, back of beach	well sorted carbonate sand, reworked from beach and other sediments
Storm ridge	supratidal	coarse comminuted shell; lag deposits of this facies underlie present day sand flat sediments
Supratidal lagoon or sabkha	supratidal, samphire	gypsiferous carbonate quartz muds, silts and sands
Estuarine	Gawler River estuary and backwaters	peat, organic mud and related sediments

In processing the laboratory samples, the high organic content made it difficult to determine the number of foraminifera with respect to a dry weight of sediment and this line of investigation was not pursued. However, all samples contained sufficient numbers of foraminifera for relative percentage analysis.

After boiling in fresh water for about an hour to break down the organic debris, samples were wet sieved and sediment of sand size (2.00–0.063 mm) was retained. Foraminifera were concentrated from these sand fractions by flotation on tetrabromoethane. Residues were inspected to ensure that most tests had been separated. The dried foraminiferal concentrates were further sieved into phi grain size fractions for microscopic examination. For each sample, percentage abundances of foraminifera species were determined for the fractions 1.00–0.50 mm and 0.50–0.25 mm.

Analysis of these fractions only, rather than the entire sample, has a number of important advantages.

Ellison (1951) has commented on the time consuming nature of quantitative foraminiferal analysis in palaeoecological studies. The work reported here was part of a more extensive investigation involving several hundred surface sediment and core samples.[2] It was important that these samples be processed efficiently. Coarser fractions require lower powers of magnification, greatly facilitating identification and separation of individual specimens.

In finer fractions, juvenile individuals constitute a high percentage of the foraminifera. Species identification is more difficult for juveniles, particularly for miliolid genera. Schnitker (1967) observed that tests of juvenile *Triloculina linneiana*, asexually produced in laboratory cultures, differed significantly in form from that of the parent. It is well known that some species of *Triloculina* may exhibit quinqueloculine coiling as juveniles, becoming triloculine only as adults (e.g. Loeblich & Tappan 1964). Such changes in form are further complicated by microspheric/megalospheric dimorphism.

In natural sedimentary systems, tests of smaller foraminifera are easily winnowed from their environments of origin to be deposited elsewhere. Also, during intraenvironmental transport, smaller, more fragile species are more prone to attrition and mechanical destruction than larger, more robust forms. Finally, when considering core samples, post diagenesis preservation will favour larger forms, less prone to solution. In this study, species of smaller genera, such as *Bulimninoides*, are considered to

generally have less value as environmental indicators than those of larger genera, such as *Peneroplis*.

In the studied size fractions twenty-eight species of foraminifera were observed. The percentage numerical distributions of the more common species, with reference to the sedimentary environments of Port Gawler, are shown in Fig. 8. These species are illustrated by scanning electron photomicrographs in Figs 9 and 10.

Systematic notes on selected species of Foraminifera

Nubecularia lucifuga is extremely variable in morphology, its shape often influenced by the object to which it adheres. Some forms are plano-convex, the flat surface usually incomplete and revealing a planispiral arrangement of chambers. A great many individuals have globular, twisted, tube-like tests, with multiple apertures and were presumably unattached. Both attached and unattached forms are recognised here as the same species.

Peneroplis planatus forms thin, translucent, planispiral tests in deeper water, but in warm, intertidal areas, where salinity rises with high rates of evaporation, tests are thick and often aberrant. The range of morphology that may be observed in such populations of *Peneroplis* has been well illustrated by Sellier de Civrieux (1970) for the Mediterranean and by Hughes-Clarke & Keij (1973) for the Persian Gulf. Similar forms occur in Port Gawler sediment and are considered here as a single species.

Spiroloculina spp. here includes *S. antillarum* and also forms having chambers of more quadrate section, lacking the numerous oblique costae of *S. antillarum*, but bearing distinct longitudinal ridges at the edges of the chambers, and often a third, parallel, and in the centre of the flat peripheral surface. Such forms are referrable to *S. tricosta* Cushman & Todd, 1944. Some individuals have been observed to have features intermediate between those definitive of these two species.

Discorbis dimidiatus is here used essentially in the sense of Hedley *et al.* (1967). They recognised that forms having greatly varying morphology, such as keeled or lobate periphery, high or low spire, large or small ventral flaps, correctly belong to a single species. All of their illustrated forms have been recognised in the Port Gawler material, and when many specimens are examined at one time, it is apparent that variation is continuous.

Elphidium macelliforme is medium to large for the genus, distinguished by its thick, lens-like form, with numerous involute, non-inflated chambers. Sutures are raised, curved and lunbate, joined by
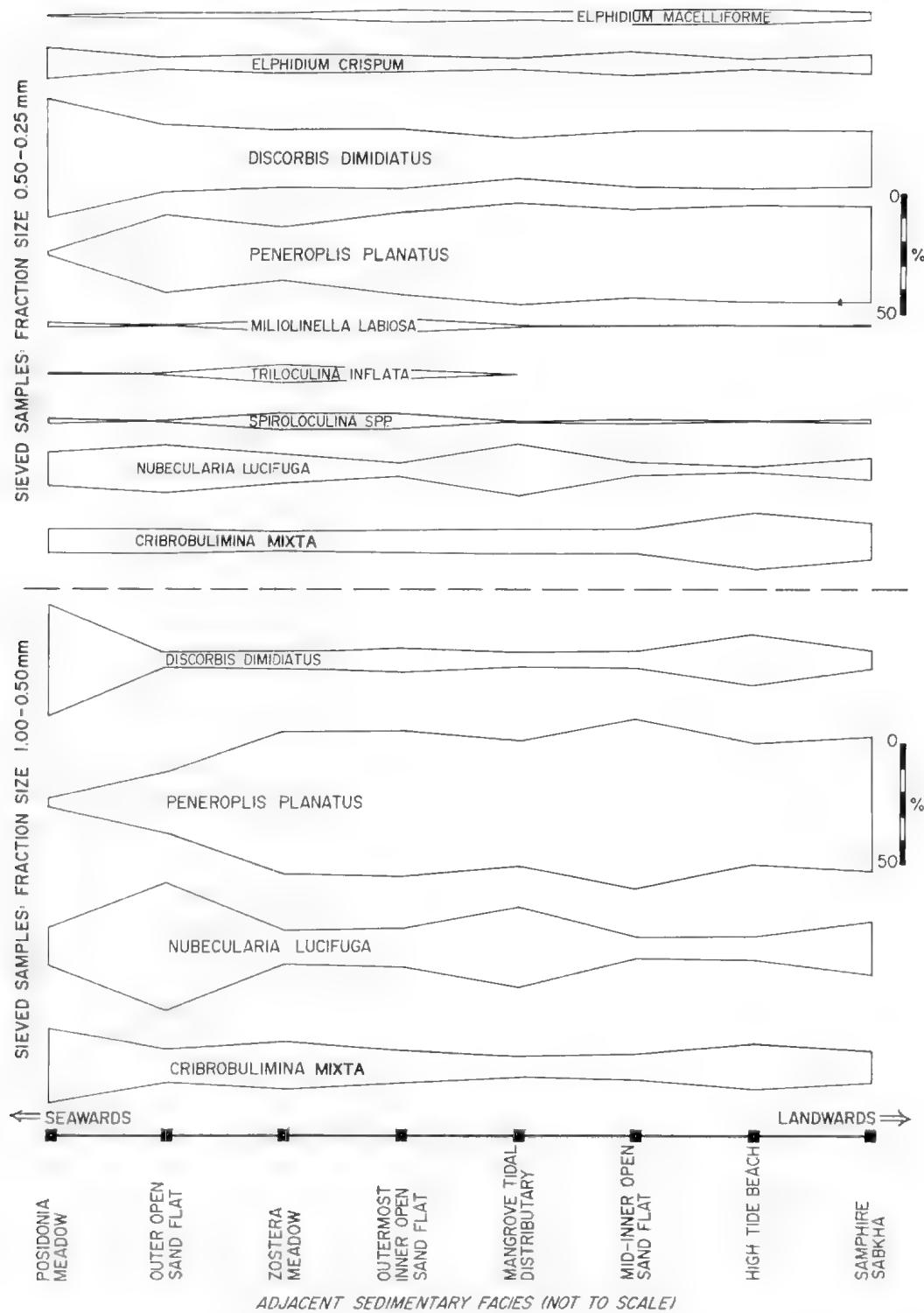
Fig. 8. Foraminiferal biofacies: relative abundance of selected species through modern, adjacent sedimentary environments, Port Gawler, South Australia.

many slender tetral processes. There is a prominent imperforate umbilical boss which is neither raised nor depressed. The interiomarginal aperture is obscured by pustular carbonate low on the apertural face. The periphery bears a low narrow keel. The surface is uniformly white and glossy.

This species, which is common in South Australian gulf waters, has only recently been described (McCulloch 1981). It is likely that in previous records of Australian Holocene foraminifera, it has been identified as *Elphidium advenum* Cushman 1922. Cushman (1922) originally described *E. advena* as having a depressed umbilical region, and lacking any significant boss or similar material. However, in subsequent work (1939) he referred forms having a rhomboid section and flush umbilical plug (e.g. Brady 1884, Pl. CX, figs. a, b) to the species. Australian workers (e.g. Chapman 1941; Parr 1945; Collins 1974) have followed this later interpretation.

Vella (1957) maintained a distinction between forms having a depressed umbilicus with a small central boss of clear shell material, and those forms having the umbilicus covered by flattened, glossy plugs not protruding beyond the outline of the shell. For the latter form Vella (1957) erected *Elphidiononion charlottensis*, which appears closely similar to the species figured by Brady, cited above.

McCulloch (1981) also believed that Cushman's later interpretation of *Elphidium advenum* included more than one species and accordingly established *Elphidium macelliforme*, described above. Her descriptions and figures agree with species occurring in the Holocene sediments of Port Gawler.

Apthorpe's *Elphidium macellum* (1980, pl. 26, fig. 11) also appears to belong to *E. macelliforme* and her *E. advena* (1980, pl. 26, fig. 10) may be a juvenile of the species.

Port Gawler vibrocores VC 136 and VC 138

Vibrocores were taken at the sites indicated in Fig. 7, VC 136 on the open inner sand flat and VC 138 in the mangrove woodland, adjacent to the Gawler River estuary. Both cores penetrated almost 3 metres of sediment.

In the laboratory, the cores were split lengthwise and lithological logs prepared. These are presented as Figs. 11 and 12. From one half, samples of approximately 100 ml of sediment were taken at 25 cm intervals and processed as described above. For each sample, percentage abundances of foraminifera were determined for the size fractions

1.00-0.50 mm and 0.50-0.25 mm. The percentage distributions of the more common species were determined. These data are shown down core for the productive intervals, here considered as St Kilda Formation, in Figs. 13 and 14.

Each core represents a sequence of near shore marine environments, recording both the initial Holocene transgression and some of the later episodes of sedimentation that followed sea level stability. The down core foraminiferal assemblages are, at least in part, indicative of those environments, and may be compared with the foraminiferal data obtained for the various facies described above.

The reliability of the data was initially tested by comparing two samples from the cyanobacterial mat facies, the first from the surface transect, the second from the top of VC 136. The sample localities were about 500 metres distant from each other on the mid-inner open sand flat.

Fig. 15 illustrates this comparison in the form of histograms. The data for the size fractions 0.50-0.25 mm are remarkably similar. That for the coarser fractions are less convincing, perhaps reflecting the smaller number of specimens counted for that size range. The number of individuals recovered from the fraction 1.00-0.50 mm were 80 and 123 for the transect and top of VC 136 respectively; equivalent numbers for the finer fraction were 211 and 717.

For the sediment size fraction 0.50-0.25 mm, where the number of individuals comprising the fraction is approximately 200 or greater, the percentage abundance of foraminifera species is considered to be a reliable environmental indicator

Results and interpretation of cores

VC 136

The earliest sediments of the St Kilda Formation recorded in vibrocore VC 136 represent the supratidal facies of the samphire zone. Fig. 16 compares the percentage abundance of species of foraminifera from the modern samphire with that observed at 50 cm in VC 136. The overlying coarse, shelly sand, sampled at 25 cm, is interpreted as remnant, storm driven shell debris. Although no foraminiferal data were determined for an actual storm ridge, the percentage abundance of species obtained for the high tide beach, developed on the seaward side of a low storm ridge, is essentially similar to that at 25 cm in VC 136. The top sample of VC 136 has been discussed above.

Fig. 9. *Trochammina inflata* (Montagu) 1808 a-c, × 120; d, × 660. *Cribrolnlimina mixta* Cushman 1927 e-f, × 40; g, × 660. *Nubeularia lucifuga* Defrance 1825 h-j, × 40. *Spiroloculina antillarum* d'Orbigny 1839 k-l, × 50. *Spiroloculina* sp. Cushman & Todd 1944 m-n, × 45. *Triloculina inflata* d'Orbigny 1826 o-q, × 60. *Miliolinella labiosa* (d'Orbigny) 1839 r-t, × 80. *Peneroplis planatus* (Fichtel & Moll) 1798 u-v, × 30.
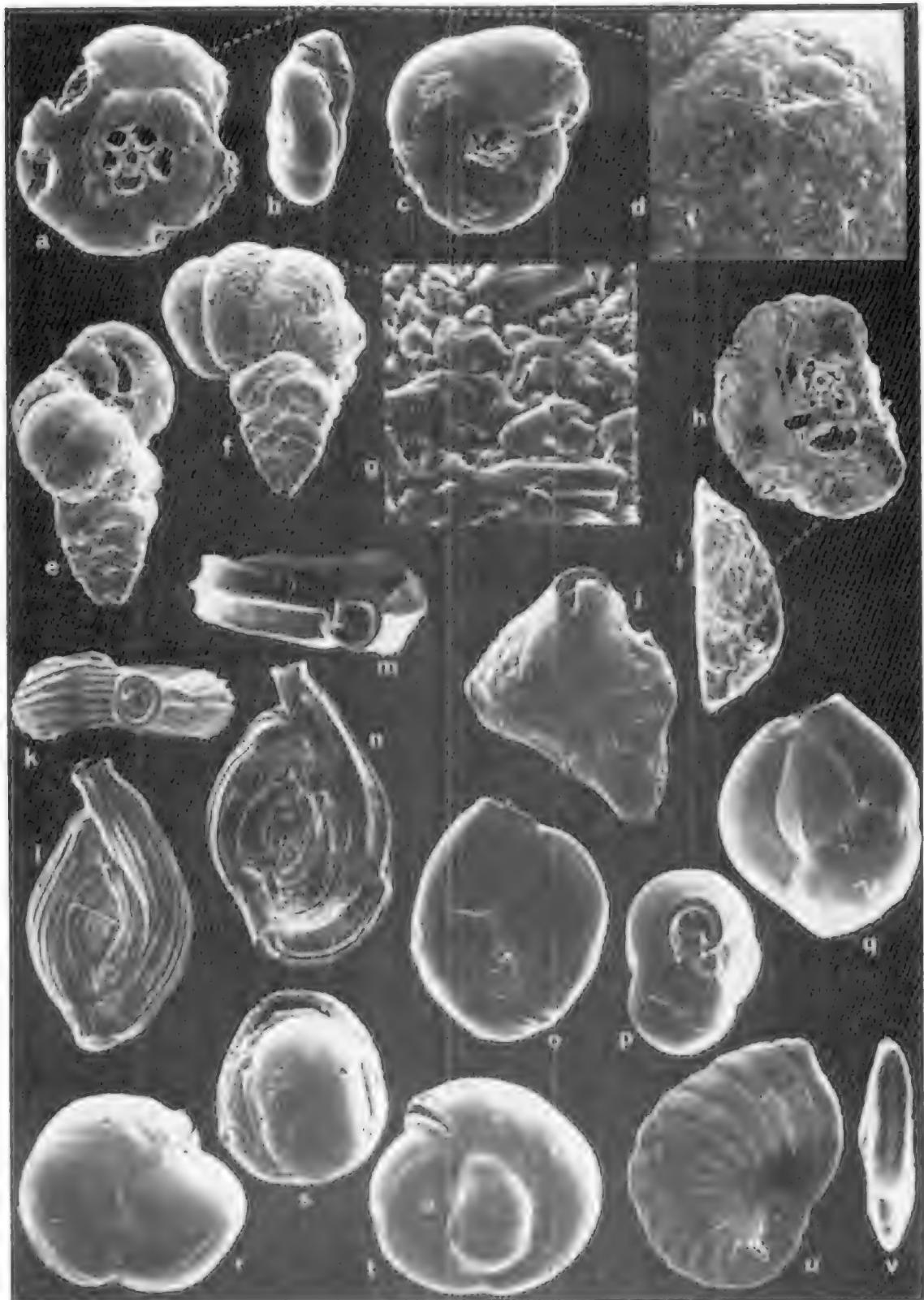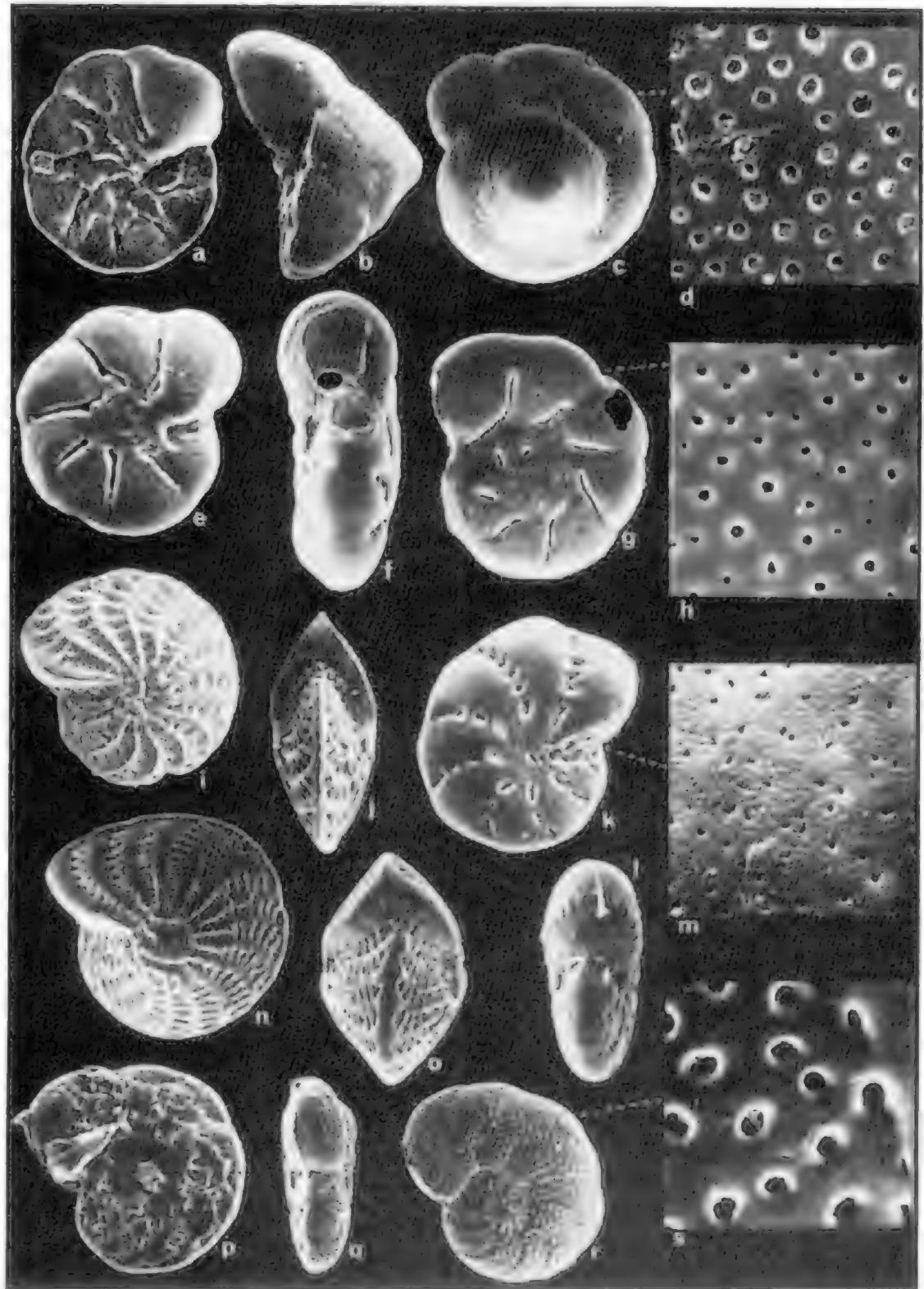
VIBROCORE VC 136

Fig. 11. Descriptive and interpretive log of Vibrocore VC 136.

Vibrocore VC 136 thus records the Holocene transgression as initially marginal marine supratidal sediments, overlain by storm debris, remnant of the episodes of storm ridge formation. The uppermost sediments are the result of aggradation on cyanobacterial mats.

VC 138

The proximity of the site of vibrocore VC 138 to the Gawler River estuary suggests that sediments penetrated by this core would have been deposited under conditions of fluctuating salinity. However, tidal channels 2 km and 2.5 km south-east of Port Gawler probably indicate former sites of debouchment of the Gawler River. The present course of the estuary has apparently developed only in later Holocene.

Although only 57 individuals are recorded at 175 cm in VC 138, for the size fraction 0.50-0.25 mm, the percentage distribution of foraminifera species agrees closely with data established for supratidal samphire sediments (Fig. 16). The distribution of species at 125 cm is very similar to that observed for the high tide beach and apparently indicates storm sediment. Thus the transgressive sequences of VC 138 and VC 136 are essentially the same.

From 100 cm to 75 cm the increase in numbers of *Spiroloculina* spp., *Miliolinella labiosa*, *Discorbis dimidiatus* and *Elphidium crispum*, with decreasing numbers of *Peneroplis planatus*, is consistent with the development of seagrasses (Fig. 17). The increase in *Ammonia beccarii*, a noted polyhaline species (e.g. Murray 1971), suggests increased influence of fresh water from the Gawler River.

A dramatic change in the foraminiferal assemblage occurs at 50 cm, as *Trochammina inflata* numbers increase from almost zero to over 70% and most other species disappear. *Trochammina inflata* is well established in the literature as an estuarine dweller (e.g. Collins 1974). Apthorpe (1980) reported the species from low salinity waters of the Gippsland Lakes, Victoria. Cann (1984) has found it to be a significant component of the fauna of the upper Onkaparinga River estuary, south of Adelaide, South Australia. The abundance of *Trochammina inflata*, reaching 100% of the fraction 0.50-0.25 mm at 25 cm, marks the development of the Gawler River estuary at its present site.

Finally, reappearance of most species in the uppermost sediment of the estuarine mangrove woodland suggests a return to conditions of tolerable salinity. If this is so, there may have been

Fig. 10. *Discorbis dimidiatus* (Parker & Jones) 1862 a-c, ×35; d, ×350. *Ammonia beccarii* (Linné) 1758 e-p, ×120; h, ×1300. *Elphidium orbiculatum* (d'Orbigny) 1839 k-l, ×140; m, ×1300. *Elphidium crispum* (Linné) 1758 t-j, ×70. *Elphidium macelliforme* McCulloch 1981 n-o, ×60. *Trichohyalus tropicus* (Collins) 1958 p-r, ×65; s, ×650. [Although *T. tropicus* abundance is less than 5% throughout both VC 136 and VC 138, it is present in significant numbers in the surface sediment of the estuarine mangrove woodland. Cann & De Deckker (1981) reported this species from a saline lake.]

VIBROCORE VC 138

Description   Environment

Yellowish brown, mottled, organic rich mud. Rare shells.   Estuarine mangrove woodland.

Dark grey to black muddy peat with live mangrove roots.   Estuary.

Light grey, moderately sorted, coarse to very coarse,
gastropod sand, with minor larger shells.   Zostera

Seagrass meadow sandflat.

Live mangrove roots and ?sea grass roots   Posidonia

Medium grey, poorly sorted, coarse shell and shell sand.   Storm debris shoreface.
Disarticulated Katelysia.   Samphire.

Medium grey, bioturbated (?crab burrows), fine, sandy, quartz silt.
Live mangrove roots.
Carbonate nodules.   Alluvial flood plain.

Light olive grey, micaceous, poorly sorted.
very fine, silty, quartz sand.

Carbonate cemented, fine quartz sand.

Yellowish grey, moderately sorted, medium, quartz sand.   River channel
Carbonate nodules and ?burrows.

Brownish grey to reddish brown,   Alluvial flood plain.
stiff, sandy mud

Penetrated 308 cm
Recovered 274 cm

Fig. 12. Descriptive and interpretive log of Vibrocore VC 138.

a real decrease in fresh water debouchment due to increasing climatic aridity, or due to human modification of fresh water drainage since European settlement of the area. Alternatively, the reappearance of these species may simply be due to the trapping of sea grass debris, with associated foraminifera tests, by the pneumatophores of recently grown mangroves.

Conclusions: six thousand years of coastal accretion

Following transgression of the post glacial Holocene sea to its present level, an ordered zonation of plant and animal communities became established. Favourable conditions ensured vigorous organic growth and rapid production of bioclastic sediment. An originally alluvial landscape was rapidly modified as storm shell ridges were thrown up along most of the coast. Saline marshlands formed landward of the ridges. The sediment redistributing effects of high tide waves and storms persisted to varying degrees along different parts of the coastline.

Around sites of debouchment of the Gawler River, deposition of estuarine muds favoured the development of seagrass, mangrove and samphire plant communities. In contrast, in the northern part of the study area, prolonged wave-dominant sedimentation gave rise to a succession of storm shell grit ridges.

The northern area is today little influenced by wave action. Only minor amounts of new sediment are being added to the high tide beach, and young mangrove trees are rapidly colonizing the *Zostera* seagrass meadow. As these new trees coalesce with the existing mangrove woodland, and with
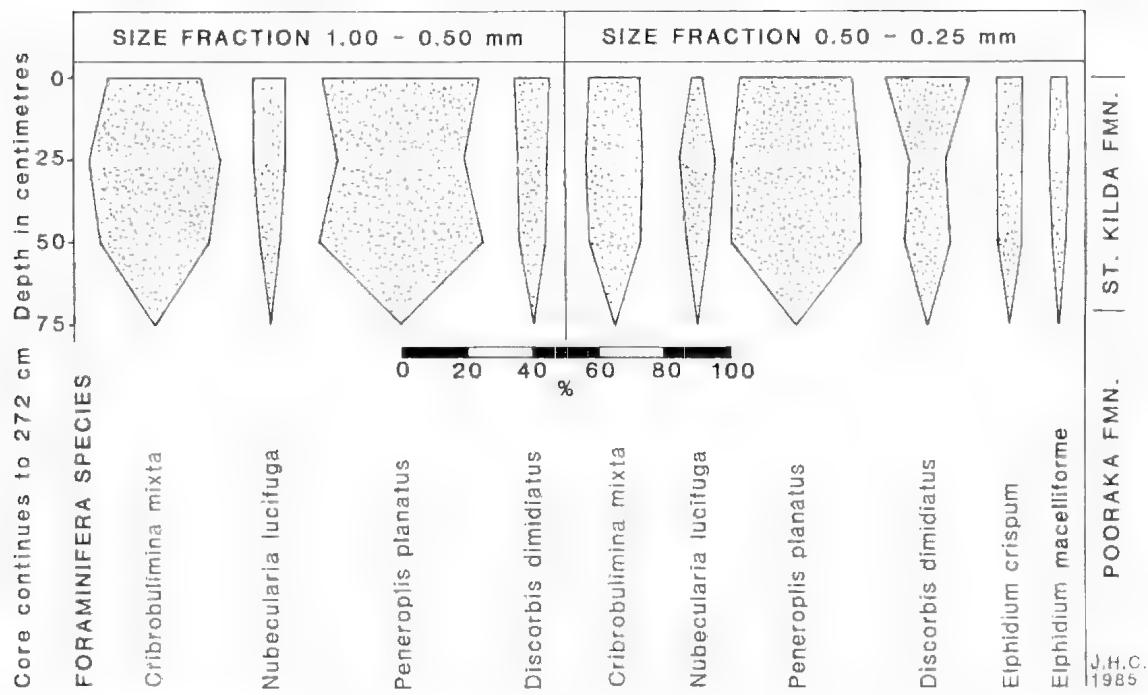
Fig. 13. Percentage distribution of selected species of foraminifera down core #VC 136, open inner sand flat, Port Gawler, South Australia.
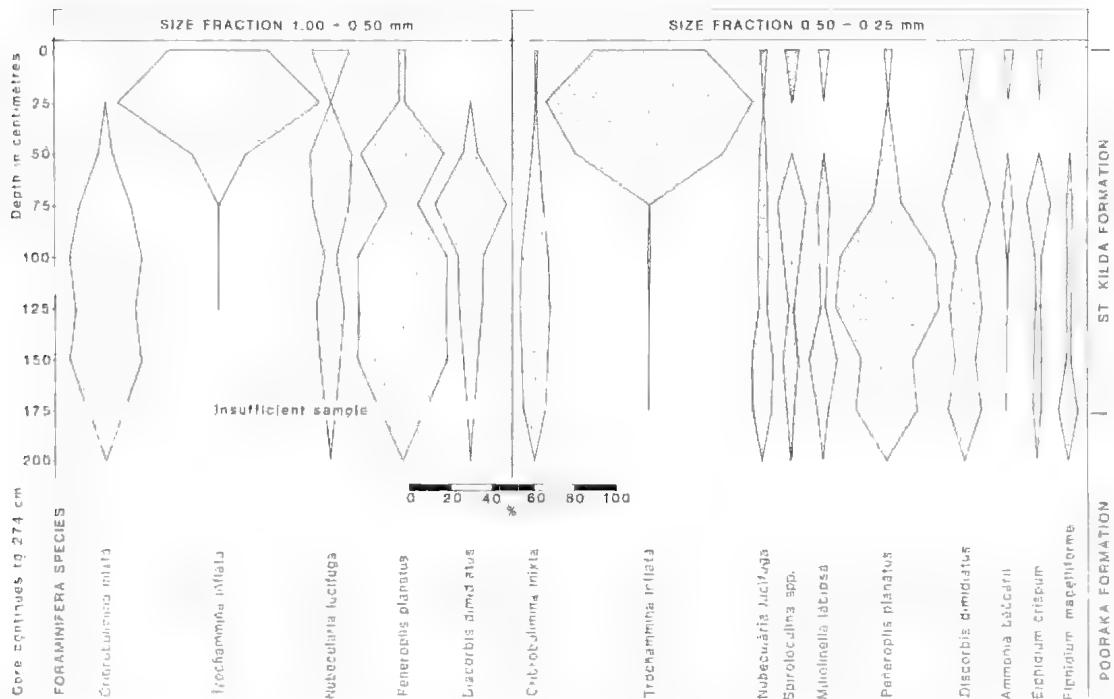
Fig. 14. Percentage distribution of selected species of foraminifera down core #VC 138, estuarine mangrove woodland, Port Gawler, South Australia.
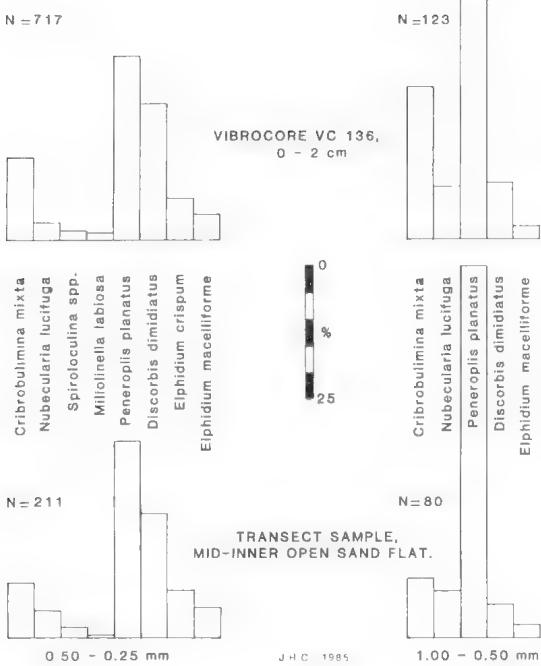
Fig. 15. Comparative percentage distributions of species of foraminifera for two samples from the inner open sandflat. N refers to the number of individuals constituting the size fraction.

continued sedimentation, the northern area will come to resemble the rest of the tide channelled samphire and mangrove coastal zone.

Thus it may be concluded that the segment of coastline discussed in this paper has evolved from saline marshlands and storm shell ridges, to a seagrass-sand flat-high tide beach zonation, formed under vigorous activity of waves (such a condition still prevails along the Adelaide metropolitan beaches), and finally to an environment of tide dominant sedimentation involving mangroves.

The following conclusions refer to the Holocene St Kilda Formation at Port Gawler.

1. The Formation consists of a number of marginal marine sedimentary facies which are closely related to different plant/animal communities.

2. The earliest sediments were transgressive, consisting predominantly of samphire muds and shelly storm debris.

3. Later sediments were formed by processes of progradation and aggradation at present day sea level. These processes are inextricably associated with various plant communities.

4. The sediments of most facies are rich in calcium carbonate, up to 90% for the shelly sands of the *Posidonia* seagrass facies.
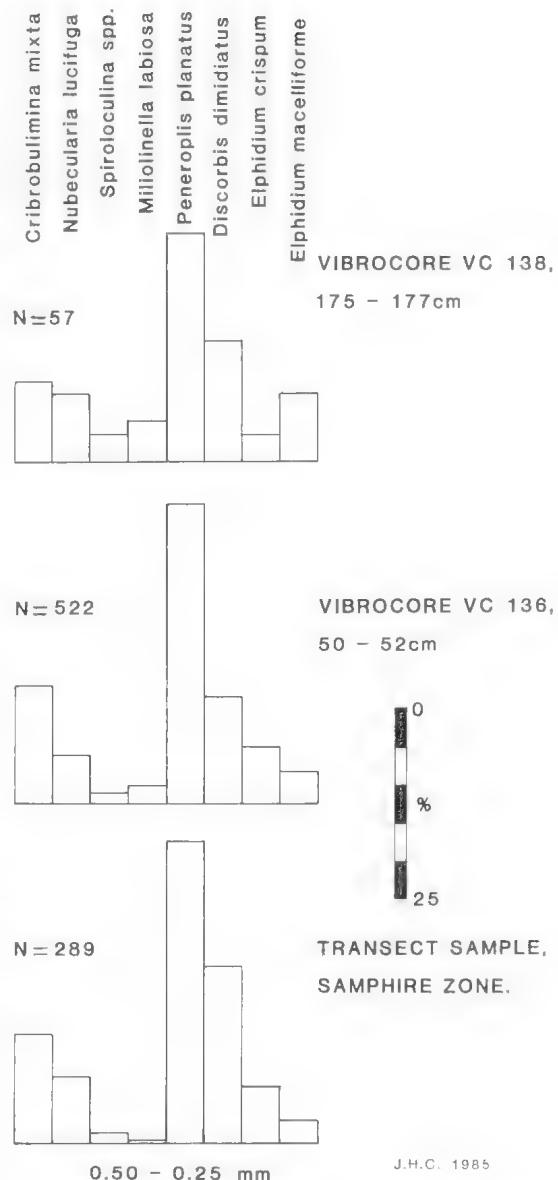
Fig. 16. Percentage distributions of species of foraminifera for samples from vibrocores VC 136 and VC 138, compared with a surface sample from the samphire zone. Only the size fraction 0.50–0.25 mm is considered. N refers to the number of individuals constituting the size fraction. The similarity of the histogram for the samphire zone and the mid-inner open sandflat (Fig. 13) reflects the landward sites of deposition and similarity of sedimentary processes.

5. Distinctive, though sometimes subtle, changes in the percentage abundance of foraminiferal species occur from one facies to another.

6. Reliable comparisons of foraminiferal biofacies can be achieved using the size fraction
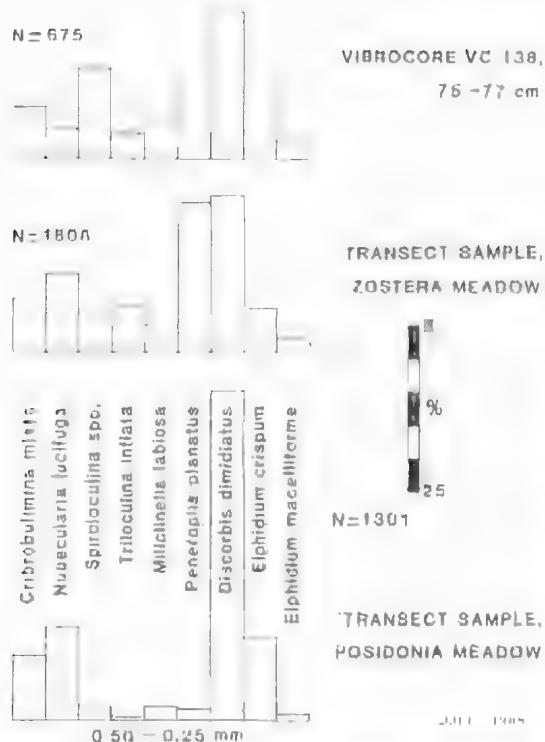
Fig. 17. Percentage distribution of species of foraminifera for surface samples from sea grassy meadows with a sample from vibrocore VC 138. Only the size fraction 0.50-0.25 mm is considered. N refers to the number of individuals constituting the size fraction

0.50-0.25 mm of floated foraminiferal concentrates.

7. Down core documentation of relative abundances of foraminiferal species, in conjunction with lithological studies, can be used to determine palaeoenvironments and thus the sedimentary history.

Acknowledgments

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REDESCRIPTION OF TWO TRICHURID NEMATODE PARASITES OF VERTEBRATES IN AUSTRALIA AND PAPUA NEW GUINEA

BY DAVID M. SPRATT

Summary

Anderson & Bain, 1982 placed Paratrichosoma Ashford & Muller, 1978 as a synonym of Capillaria (sensu latu) Zeder, 1800. The reasons for this synonymy are discussed herein and Capillaria crocodilus (Ashford & Muller, 1978) comb. nov. from tunnels in the epidermis of Crocodylus novaeguineae Schmidt in Papua New Guinea is redescribed from co-type specimens.

REDESCRIPTION OF TWO TRICHURID NEMATODE PARASITES OF VERTEBRATES IN AUSTRALIA AND PAPUA NEW GUINEA

by David M. Spratt[*]

Summary

Spratt, D. M. (1985) Redescription of two trichurid nematode parasites of vertebrates in Australia and Papua New Guinea. *Trans. R. Soc. S. Aust.* 109(4), 143-150, 29 November, 1985.

Anderson & Bain, 1982 placed *Paratrichosoma* Ashford & Muller, 1978 as a synonym of *Capillaria* (sensu latu) Zeder, 1800. The reasons for this synonymy are discussed herein and *Capillaria crocodilus* (Ashford & Muller, 1978) comb. nov. from tunnels in the epidermis of *Crocodylus novaeguineae novaeguineae* Schmidt in Papua New Guinea is redescribed from co-type specimens.

Trichosomoides nasalis Biocca & Aurizi, 1961 is described and illustrated from the nasal cavity of *Rattus fuscipes* (Waterhouse) in southeastern New South Wales. This represents the first record of the parasite in Australia and *R. fuscipes* is the only murid host known to date.

Key Words. *Paratrichosoma*, *Capillaria*, *Trichosomoides*, Nematoda, distribution, hosts, morphology, Muridae.

Introduction

The Trichuridae is a cosmopolitan family of parasitic nematodes which are poorly understood, both morphologically and biologically. During study of the trichurids of Australasian vertebrates the need arose to re-examine two unusual species, one described originally as *Paratrichosoma crocodilus* Ashford & Muller, 1978 from *Crocodylus novaeguineae novaeguineae* Schmidt at Moitaka crocodile farm, Port Moresby, and *Trichosomoides nasalis* Biocca & Aurizi, 1961 first reported from *Rattus norvegicus* (Berkenhout) in Rome (Aurizi, 1958) and not known to occur in rats in Australia. Redescription of these species and consideration of their taxonomic placement form the basis of this report.

Materials and Methods

Nematodes were fixed in hot, 10% neutral buffered formalin and cleared in lactophenol.

Co-types of *T. nasalis* were kindly loaned to me by Professor E. Biocca of the Istituto di Parassitologia dell' Università di Roma. Loan of male and female paratypes of *Paratrichosoma crocodilus* was kindly arranged by Mrs E. A. Harris of the British Museum.

Measurements were made with the aid of an ocular micrometer, drawing tube, and measuring wheel, and are presented in micrometers unless otherwise stated. Where possible, the range of measurements is followed by the mean, in parentheses. Illustrations were made with the aid of a drawing tube.

Type specimens have been returned to their respective institutions. Representative specimens of

* Division of Wildlife & Rangelands Research, CSIRO, P.O. Box 84, Lyneham, A.C.T. 2602.

T. nasalis from *R. fuscipes* in Australia have been deposited in the British Museum (Natural History) (B.M.(NH) No. 1981/3537-3540), the Istituto di Parassitologia dell' Università di Roma, the Muséum national d'Histoire naturelle, Paris (MN 476 HB), the South Australian Museum (V3244), the Australian Helminthological Collection (13855), the United States National Museum Helminthological Collection No. 77454 and the helminth collection of the Division of Wildlife and Rangelands Research, CSIRO (N498, 717, 882).

Capillaria crocodilus (Ashford & Muller, 1978) comb. nov.
FIGS 1-7

Material examined: from *Crocodylus novaeguineae novaeguineae* Moitaka crocodile farm, Port Moresby, 1♂, 1♀ paratypes, BM(NH) coll. No. 1978/917-920.

Redescription

Long thin nematodes with attenuated anterior and blunt posterior extremities. Cuticle exceptionally thick, cuticular striae not observed. Two exceptionally broad lateral and one narrow ventral bacillary bands. Hypodermal gland cells of bands papilla-like in appearance due to necessity for neck of cell to traverse thick cuticle to external pore opening. Lateral alae absent. Cephalic extremity minute, with minute dome possibly consisting of two lips; stylet and buccal capsule not observed. Oesophagus commencing as narrow muscular tube, broadening posterior to nerve ring, narrowing before reaching stichosome, passing through stichosome on dorsal or lateral surface but exiting from it on ventral surface as narrow muscular duct. Stichosome not extending as far as intestine. Narrow muscular oesophagus forming unusual opaque junction with intestine, consisting of two rather than three tissue segments and not
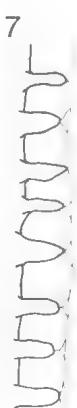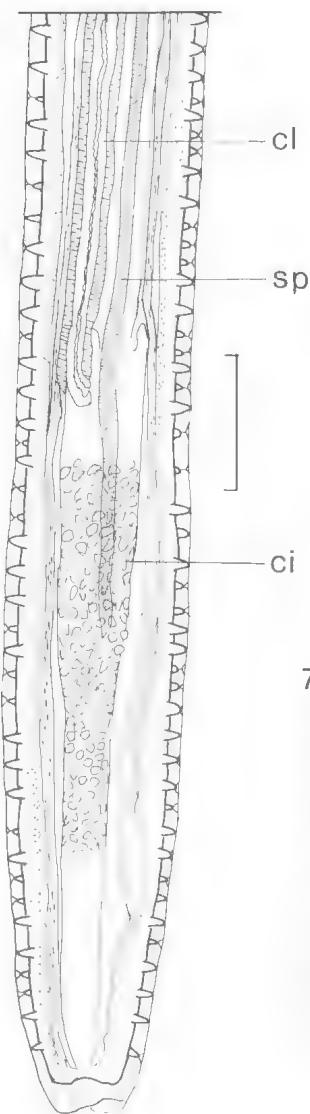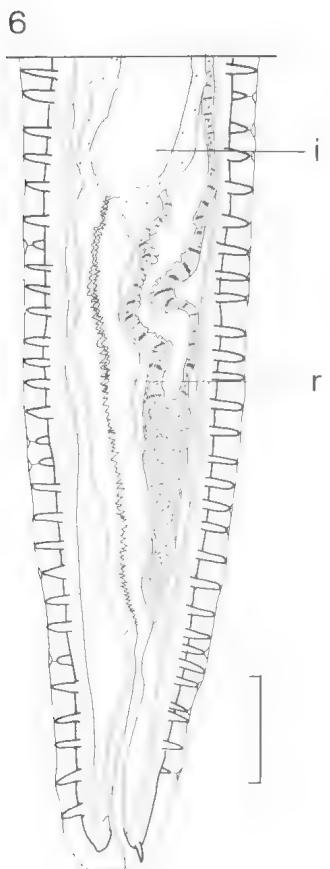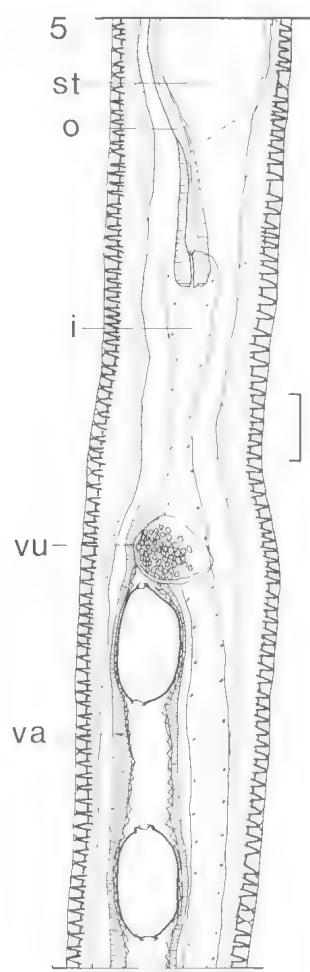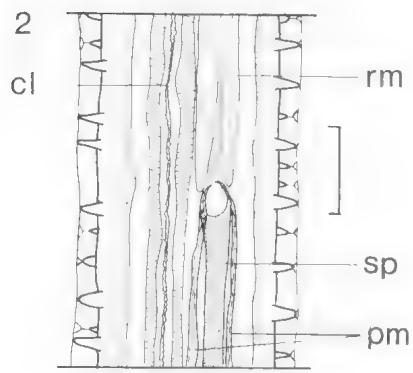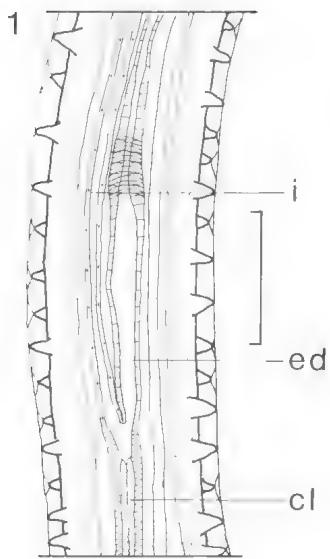
appearing as true valve. Two mesenchymal cells not present at oesophago-intestinal junction. Stichosome composed of approximately 36 stichocytes, much longer than wide, large nucleus not observed in each stichocyte. Intestine large and conspicuous. Tail broad and blunt, without papillae in female and without alae in male. Anus and cloaca terminal in female and male respectively. Male with short ejaculatory duct, long cloaca lined with cuticle, long robust non-sclerotised spicule, and spicule sheath (=cirrus *sensu* Anderson & Bain, 1982) with robust blunt spines or scales. Female with vulva slightly posterior to oesophago-intestinal junction, vagina vera lined with cuticular spines or scales. Eggs moderately thick-shelled, untanned, shell without ornamentation, eggs in distal uterus not embryonated.

Male

Length 22.7 mm. Width at nerve ring 30, at oesophago-intestinal junction 57; maximum width 66. Length of muscular oesophagus 300; total length of oesophagus 13.6 mm. Length of stichosome 13.2 mm; stichocytes 33 in number; length of stichocytes 260–330. Nerve ring 50 from cephalic extremity. Total length of cloaca 930; length of spiny spicule sheath 150; length of ejaculatory duct 100; spicule pouch entering cloaca 213 from caudal extremity. Spicule present, not sclerotised, 450 in length, 8 in maximum width, capitulum with characteristic "bubble" shape, spicule broad proximally, with broad but tapering point distally. Junction of intestine and ejaculatory duct simple, both ducts same width at junction. Spicule sheath with robust but generally blunt spines or scale-like ornamentation (not everted in this specimen). Spicule retractor muscle inserting 150 anterior to sphincter muscle delineating modification of distal vas deferens into ejaculatory duct.

Lateral and ventral bacillary bands commencing in region of nerve ring; lateral bands 2–3 cells wide, cells regular in distribution; ventral band one cell wide, cells irregular in distribution. Lateral bands broadening rapidly, 10–13 cells in width approximately 5 mm posterior to cephalic end and practically encircling worm; bands narrowing abruptly near tail tip, 7 cells in width at level of entry of spicule pouch to cloaca. Ventral bacillary band with single column of cells spaced irregularly along body length.

Female

Length 67.5 mm. Width at nerve ring 70, at vulva 113; maximum width 135. Length of muscular oesophagus 270; total length of oesophagus 19.2 mm. Length of stichosome 18.7 mm; stichocytes 37 in number; length of stichocytes 300–580. Nerve ring 60 from cephalic extremity. Vulva 20.2 mm from anterior extremity. Vagina vera 109 long, lined with thick cuticular scales similar in morphology to those on male cirrus. Rectum 201 long, lined with thick cuticle. Anus terminal.

Lateral and ventral bacillary bands commencing in region of nerve ring. Lateral bands 4–6 cells wide, cells regular in disposition; ventral band one cell wide, cells irregular in disposition. Lateral bands broadening rapidly, 10–13 cells in width approximately 5 mm posterior to cephalic extremity, practically encircling worm; bands narrowing abruptly approximately 0.5 mm from tail tip. Ventral bacillary band with single column of cells spaced irregularly along body length.

Discussion

My observations differ markedly from those of Ashford & Muller (1978). This trichurid nematode species from epidermal tunnels in the abdominal skin of crocodiles possesses (i) conspicuous bacillary bands comprised of papilla-like hypodermal gland cells due to the neck of the gland cell having to traverse the thick body cuticle to the external pore opening, (ii) a stichosome comprised of 32–37 elongate stichocytes arranged in a single column, (iii) a long broad non-sclerotised spicule, (iv) a spicule sheath with robust blunt spines and scale-like ornamentation, (v) a long muscular cloaca with thick cuticular lining and (vi) unembryonated eggs in the distal uterus of the female, none of which were reported by Ashford & Muller (1978). The caption to their Fig. 5 contradicts their statement on p. 216, "Eggs unembryonated when laid" and should read, "Egg from skin, containing a larva".

The abovementioned features are characteristic of the trichurid nematode subfamily Capillariinae

Figs 1–7 *Capillaria crocodilus* (Ashford & Muller, 1978) comb. nov. 1. Male posterior end showing junction of intestine and ejaculatory duct with distal cloaca. 2. Male posterior end showing capitulum of spicule, spicule retractor and protractor muscles, and cloaca. 3. Male caudal end showing cloaca, spiny spicule sheath and distal end of spicule. 4. Blunt spines and scale-like ornamentation on spicule sheath of male. 5. Female anterior end showing oesophago-intestinal junction, vulva and vagina with scale-like ornamentation, ventral view. 6. Female caudal end, ventral view. 7. Lateral bacillary band of female showing neck of gland cells traversing thick cuticle to exterior pore openings. Scale lines: Figs 4, 7, 10 μm; Fig. 2, 20 μm; Figs 1, 3, 5, 50 μm. Abbreviations: ss—spicule sheath (=cirrus *sensu* Anderson & Bain, 1982), cl—cloaca, ed—ejaculatory duct, i—intestine, o—oesophagus, pro—protractor muscle of spicule, r—rectum, rm—retractor muscle of spicule, sp—spicule, st—stichocyte, va—vagina, vu—vulva.

(*sensu* Anderson & Bain, 1982) and differ from the Trichosomoidinae to which Ashford & Muller allocated their genus. In contrast, members of the Trichosomoidinae possess a primitive oesophagus with 60 to 150 stichocytes sometimes arranged in two or three columns, males have a short cloaca but lack both a spicule and a spicule sheath, and eggs are embryonated when laid by female worms. Anderson & Bain, 1982 placed *Paratrichosoma* Ashford & Muller, 1978 as a synonym of *Capillaria (sensu latu)* Zeder, 1800. The reasons for this synonymy are presented above and the crocodile parasite is formally recognised as *Capillaria crocodilus* (Ashford & Muller, 1978) comb. nov.

Despite the foregoing, *C. crocodilus* possesses several features which distinguish it from many other members and which may warrant consideration in any future comprehensive revision of the genus *Capillaria*. These are as follows: (i) exceptionally thick cuticle, (ii) exceptionally broad lateral bacillary bands, (iii) anterior muscular oesophagus with median swelling similar to that occurring in first-stage larvae of the Metastrongyloidea, (iv) exceptionally long stichocytes, (v) stichosome terminating well anterior to oesophago-intestinal junction (vi) form of oesophago-intestinal junction, (vii) absence of two mesenchymal cells at oesophago-intestinal junction, (viii) absence of alae or papillae on male and female caudal extremities, (ix) vagina vera lined with cuticular scales similar to those on spicule sheath of male and (x) insertion of spicule retractor muscle well anterior to (rather than at level of) sphincter muscle delineating modification of distal vas deferens into ejaculatory duct.

Ashford & Muller (1978) reported that two crocodiles, *C. novaeguineae novaeguineae* and *C. porosus* Schneider were susceptible to infection with *Capillaria crocodilus*, that the parasite was rare or absent in crocodiles from areas of saline water and that transmission of the parasite does not occur under some rearing conditions on crocodile farms. Undulating nematode worm trails, probably attributable to *C. crocodilus*, have been reported from *C. acutus* Cuvier (Garrick in Webb & Manolis, 1983), *C. intermedius* Graves (King & Brazaitis, 1971), *C. johnstoni* (King & Brazaitis, 1971; Webb & Manolis, 1983) *C. moreletii* Duméril, Bibron and

Duméril (King & Brazaitis, 1971), *C. niloticus* Laurenti (King & Brazaitis, 1971) and *C. porosus* (King & Brazaitis, 1971; Webb & Messel, 1977).

In the Northern Territory of Australia worm trails are more common in larger specimens of both *C. johnstoni* and *C. porosus* (Webb & Messel, 1977; Webb & Manolis, 1983). In Queensland, worm trails occur in *C. johnstoni* 3 years of age and older, and there is an increasing prevalence and density of trails with age. (K. R. McDonald, pers. comm.).

Other species of *Capillaria (sensu latu)* (Capillariinae) occur in the skin both of cold-blooded and of warm-blooded vertebrate hosts (Gallego & Mas-Coma, 1975; Moravec & Cosgrove, 1982; Wade, 1982). In addition, Lyne & Sommerville (1965) reported a species of *Capillaria* in skin sections of the lip and scrotum of the marsupial bandicoot, *Perameles nasuta* Geoffroy in Australia. I have recovered adults of species of *Capillaria* from these sites in *P. nasuta* and *Perameles gunnii* Gray, and from epithelial tunnels in the tongue of *P. gunnii*, *P. nasuta* and the small dasyurid marsupials *Antechinus stuartii* Macleay and *A. swainsonii* (Waterhouse). The genera *Anatrichosoma* and *Trichosomoides* (Trichosomoidinae) also contain species which occur in tunnels or burrows in the epithelial tissues of their mammalian hosts (see Discussion in Spratt, 1982 and this paper).

Trichosomoides nasalis Biocca & Aurizi, 1961
FIGS 8–21

Specimens of *Trichosomoides nasalis* were found in the mucosa of the distal nasal cavity of 5 of 232 *Rattus fuscipes* examined from forested coastal and montane habitats (sea level to 1220 metres) in southeastern New South Wales. The parasite was not found in 77 *R. lutreolus* (Gray), 13 *R. rattus* L., 97 *Mus musculus* L. and 8 *Mastacomys fuscus* Thomas examined from these same regions. Numbers of female nematodes recovered from individual rats were 4–34 ($\bar{x}=12$), those of males living in the uteri of females 2–8 ($\bar{x}=5$).

Material examined: from *Rattus (=Epimys) norvegicus*, Rome, Italy, T. Crapulli, co-type ♀ containing 2 co-type ♂♂ *in utero*, fragments 2 co-type ♀♀, 1958, in Istituto di Parassitologia dell' Università di Roma.

Figs 8–21. *Trichosomoides nasalis* Biocca & Aurizi, 1961 from *Rattus fuscipes*. 8. Anterior end, female, dorsal view. 9. Oesophago-intestinal junction and vulva of female, lateral view. 10. Caudal end of gravid female, lateral view. 11. Caudal end of non-gravid female, lateral view. 12. Cephalic end female, *en face* view. 13. Egg from distal vagina of gravid female. 14. Egg adjacent to that in Fig. 13, opposite profile. 15. Anterior end male, lateral view of cuticular ornamentation—pore openings of hypodermal gland cells interrupted by partial but conspicuous transverse striae. 16. Anterior end male, lateral view. 17. Oesophago-intestinal junction, male, lateral view. 18. Caudal end male, lateral view. 19. Elevated hypodermal gland cells of bacillary band in posterior half of female, lateral view. 20. Lateral bacillary band, mid-body region of female. 21. Lateral bacillary band 0.5 mm from caudal end of female. Scale lines: Fig. 12, 10 μm; Figs 13, 14, 20 μm; Figs 8, 10, 11, 13, 21, 50 μm; Fig. 9, 100 μm.
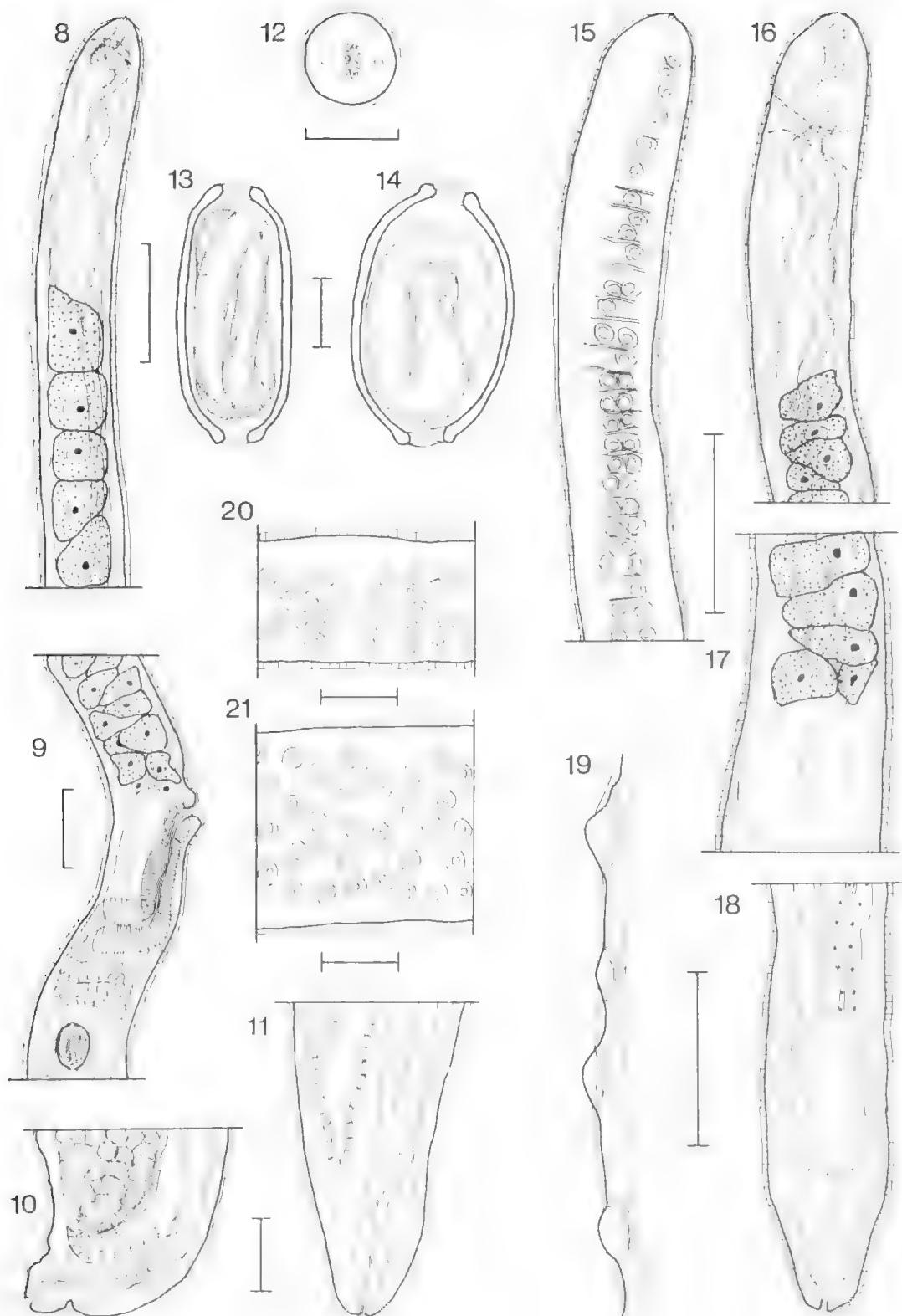
From *R. fuscipes,* Lee's Creek, A.C.T., P. Haycock and D. M. Spratt, 15♀♀, 66♂♂, 22.i.1979; Bundarra Creek, Snowy Plains, N.S.W., D. M. Spratt, 34♀♀, 91♂♂, 22.ii.1978; Emu Creek, Bondo State Forest, near Bondo N.S.W., P. Haycock and D. M. Spratt, 6♀♀, 21♂♂, 24.xi.1978; Nadgee State Forest, near Eden N.S.W., P. Haycock and D. M. Spratt, 7♀♀, 23♂♂, 12.xii.1978; E. Walter and P. Haycock, 5♀♀, 28♂♂, 1.xii.1982.

Redescription

Female relatively long and narrow, with slightly attenuated anterior and blunt posterior extremities. Male minute, occurring in uterus and vagina of female.

Female (measurements of 18 specimens)

Length 6.5–15.7 (11.9) mm. Width at nerve ring 30–34 (32), at oesophago-intestinal junction 60–100 (84); maximum width 90–200 (150). Cuticle thin, with conspicuous, closely-spaced transverse striae anteriorly, less conspicuous in midbody, barely discernible posteriorly. Cephalic end narrow bearing single stylet, able to be retracted into minute buccal capsule. Oral opening dorso-ventrally elongate, with 6 minute lips each bearing single papilla. Amphids relatively large, papilliform. Oesophagus commencing as narrow muscular tube, broadening posterior to nerve ring, narrowing as it enters stichosome, passing laterally through stichocytes. Length of muscular oesophagus 120–200 (160); total length of oesophagus 1.38–2.41 (1.80) mm. Length of stichosome 1.20–2.21 (1.64) mm. Number of stichocytes 69–84 (74), anterior stichocytes regularly aligned in single column, posterior ones irregularly aligned in 1, 2 or 3 columns; cells approximately square, becoming more triangular in posterior half of stichosome, all with single large nucleus. Nerve ring 18–50 (26) from cephalic extremity. Oesophago-intestinal junction conspicuous, with two small mesenchymal cells, 1 dorsal, 1 ventral, each with single large nucleus. Vulva 1.40–2.45 (1.83) mm from anterior extremity, with small lip on each of anterior and posterior margins, with exceptionally thin cuticular lining. Vagina vera 132–167 (150), muscular, with exceptionally thin cuticular lining. Posterior intestine with narrow lumen and relatively thick muscular walls in immature females, with wide lumen and thin muscular walls in gravid females. Rectum with thick cuticular lining. Anus terminal, without lips or swelling. Tail blunt, often twisted or distorted in gravid females.

Lateral bacillary bands commencing in region of nerve ring as column 1–2 cells wide, broadening to 3–4 cells width at posterior end of stichosome, cells arranged irregularly. Bands becoming much wider just anterior to or level with vulva, extremely wide from here to posterior end and leaving only narrow dorsal and ventral columns of cuticle unornamented except for diminishing transverse striae. In this region hypodermal gland cells projecting above level of body cuticle, papilliform, with single pore opening at apex, most pronounced in posterior half of body in gravid females. Lateral alae not observed.

Eggs in distal uterus 70–80 (75) long, 34–76 (40) wide, variable in shape, thin in one profile thick in opposite, plugs not protruding, shell dark amber brown, smooth; eggs containing larvae; larvae hatching in distal uterus in some specimens.

Females containing 2–8 (5) males, usually in distal uterus or muscular vagina of non-gravid females, usually in posterior uterus of gravid females. One female with anterior half of male protruding from vulva.

Male (measurements of 10 specimens)

Length 1.25–1.65 (1.38) mm. Width at nerve ring 22–32 (28), broadening in posterior half; maximum width 40–70 (54). Cuticle with conspicuous transverse striae throughout. Cephalic end with two minute lateral papilliform structures, presumably amphids. Buccal capsule minute, 4–6 (5) long, stylet not observed. Oesophagus commencing as broad muscular tube, narrowing posteriorly as it enters stichosome, passing laterally through stichocytes. Length of muscular oesophagus 60–110 (87); total length of oesophagus 530–630 (582). Length of stichosome 440–530 (493). Stichocytes as described in female, cell walls often indistinct making counting difficult; approximate number stichocytes 65–74. Nerve ring 25–34 (28) from cephalic extremity. Oesophago-intestinal junction indistinct. Intestine broad, thick-walled. Intestine and vas deferens uniting to form short muscular cloaca, 70–80 (76), without cuticular lining anteriorly. Cloaca modified distally into short thick-walled cuticular duct without musculature, 30–37 (34). Spicule absent. Spicule sheath absent. Tail blunt, cloacal opening terminal.

Lateral bacillary bands similar to those in female, not as broad, with fewer gland cells. Bands commencing as column of single cells posterior to buccal capsule, broadening to column 2 cells wide posterior to nerve ring, continuing throughout body length as column 2–3 cells wide. Gland cells becoming papilliform near posterior end of stichosome, projecting above level of body cuticle, each with single pore opening at apex. Gland cell openings separated or grouped in lots of 2 or 3 by short conspicuous transverse striae.

Discussion

Members of the genus *Trichosomoides* are parasites of the mucosal surfaces of murid rodents. Only two species are known; *T. crassicauda*

(Bellingham, 1865) Railliet, 1895 from the urinary tract, generally the bladder, of wild and laboratory rodents throughout the world, and *T. nasalis* Biocca & Aurizi, 1961 from the nasal cavity of *R. norvegicus* in Rome. This species was recorded in the wild for only the second time by Cross *et al.* (1970) who reported a prevalence of 4.2% in *R. exulans* (Peale) in Central Java, Indonesia. Later, Cross & Santana (1975) reported *T. nasalis* in 24% of *R. coxingi* Swinhoe examined on Taiwan. Number of worms per infected host ranged from 1–15 with a mean number of 4.5 nematodes per animal. Bernard (1964) described *T. gerbillis* from the stomach of *Gerbillus pyramidum hirtipes* Lataste in Tunisia but this was later transferred to *Anatrichosoma* (Pence & Little, 1972). Males of the genus *Trichosomoides* are unique among parasitic nematodes for their habit of dwelling in the uterus and vagina of the female worm.

Morphological differences between *T. nasalis* from *R. norvegicus* in Rome and the specimens from *R. fuscipes* in southeastern Australia are slight. Biocca & Aurizi (1961) illustrated 59 stichocytes in the stichosome of the female. A variable number of stichocytes occur in male and female nematodes from *R. fuscipes* and I observed 70 stichocytes in a co-type female fragment (non-gravid) from *R. norvegicus*. Measurements of morphological features of both male and female *T. nasalis* from *R. norvegicus* reported by Biocca and Aurizi (1961) and observed by me are slightly greater than those of specimens from *R. fuscipes*. These differences are viewed as insignificant, possibly host-induced and certainly not warranting separate specific status for the material from *R. fuscipes* in Australia, which is here recognised as *T. nasalis*.

A characteristic feature of male and female *T. nasalis* is the form of the lateral bacillary bands, particularly in the posterior half of the body. In this region the hypodermal gland cells project above the body cuticle, are papilliform or dome-shaped and bear a single pore opening at their apex. This feature was observed by Biocca & Aurizi (1961)—". . . papilla-like cuticular elevations nearly 10 μm in diameter."—and may be seen in their illustration of the female nematode. These authors' observation of the conspicuous nature of the elevations on the ventral surface of female worms is misleading. The bacillary bands originate on the lateral surfaces but become extremely wide posterior to the vulva, leaving only narrow dorsal and ventral columns of cuticle without gland cell pore openings, and thus unornamented, except for weak transverse striae. Spratt (1982) commented on the similarity in form of the hypodermal gland cells in species of *Trichosomoides* and three members of the genus *Anatrichosoma*.

The records of *T. nasalis* in *R. exulans* in Indonesia, *R. coxingi* on Taiwan and now in indigenous *R. fuscipes* in Australia add weight to the suggestion that this nematode species may be widely distributed throughout the world (Cross *et al.*, 1970; Cross & Santana, 1975).

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AUSTRALIAN AND NEW ZEALAND SPECIES OF ELACHISTA AND HALOTHRIX (ELACHISTACEAE, PHAEOPHYTA)

BY S. SKINNER

Summary

Three species of Elachista Duby, E. claytoniae sp. nov., E. australis J. Ag. (Syn. Portphillipia australis (J. Ag.) and E. orbicularis (Ohta) Skinner and one species of Halothrix Reinke, H. ephemeralis sp. nov. are described from southern Australia. E. australis and E. lindaueri Chapman are described from New Zealand, and a key is given to the Australia and New Zealand taxa of Elachista. The systematics of the genus Elachista are discussed.

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Summary

SKINNER, S (1985) Australian and New Zealand species of *Elachista* and *Halothrix* (Elachistaceae, Phaeophyta). *Trans. R. Soc. S. Aust.* **109**(4), 151-160, 29 November, 1985.

Three species of *Elachista* Duby, *E. claytoniae* sp. nov., *E. australis* J. Ag. (Syn. *Portphillipia australis* (J. Ag.) Silva) and *E. orbicularis* (Ohta) Skinner and one species of *Halothrix* Reinke, *H. ephemeralis* sp. nov., are described from southern Australia. *E. australis* and *E. lindaueri* Chapman are described from New Zealand, and a key is given to the Australia and New Zealand taxa of *Elachista*. The systematics of the genus *Elachista* are discussed.

KEY WORDS: *Elachista*; *E. claytoniae* sp. nov.; *E. australis*; *E. orbicularis*; *E. lindaueri*; *Halothrix*; *H. ephemeralis* sp. nov., *Portphillipia*; Elachistaceae; Chordariales; Phaeophyta; southern Australia

Introduction

The family Elachistaceae includes three genera and about 30 species, and is usually placed in the order Chordariales. The absence of any hair-like structures and the presence of determinate cortical assimilatory filaments ("paraphyses") in combination with long, indeterminate assimilatory filaments clearly separate this family from other families in the order. The pulvinate thallus is composed of a filamentous medullary system which radiates from a basal layer and supports a cortex of both determinate assimilatory filaments and reproductive structures, beyond which project the long assimilatory filaments. The cells of assimilatory filaments of all three genera contain a large central nucleus, numerous discoid phaeoplasts with many species having prominent pyrenoids projecting from the phaeoplasts, and some physodes. All are epiphytes.

The genera included in the family are *Halothrix* Reinke, epiphytic on seagrasses, *Elachista* Duby (including *Symphoricoccus* Reinke and *Portphillipia* Silva), epiphytic on larger algae, and *Herpodiscus* South (1974), epiphytic on *Durvillaea*. *Elachista* species are found as epiphytes on various Phaeophyta and Rhodophyta, with one species (*E. zosterae* Noda in Noda & Kitami 1971) on a marine angiosperm. Plurilocular sporangia, which are produced by most species, are uniseriate, filiform and are borne on sporangiophores among the cortical assimilators.

Halothrix differs from *Elachista* by having intercalary plurilocular sporangia which develop, in a sorus, in cells within the long assimilatory filaments. It also shows relatively fewer phaeoplasts in the photosynthetic cells, and, at least in *H.*

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lumbricalis (Kütz.) Reinke, a greater development of rhizoidal filaments buttressing the medulla—both of these differences are ones of degree rather than contrast with *Elachista*. The hosts of *Halothrix* are usually marine angiosperms (*Zostera, Heterozostera* and *Phyllospadix*).

Elachista (= *Portphillipia*) *australis* J. Agardh has been recorded from Victoria and Tasmania (Womersley 1967) and *E. orbicularis* (Ohta) Skinner from Western Australia and South Australia (Skinner 1983). The present study shows that there is also one further species of *Elachista* and at least one of *Halothrix* in southern Australian waters. In New Zealand, two species of *Elachista* have been recorded, *E. australis* in the south, and the endemic *E. lindaueri* Chapman.

A subantarctic species of *Elachista*, *E. antarctica* Skottsberg 1953, is also included in the key because of its recent discovery on Macquarie Island (Ricker pers. comm.)

Key to the Genera

1. Plant pulvinate to spreading, epiphytic on larger algae; cells of long assimilatory filaments with numerous packed phaeoplasts; plurilocular sporangia, when present, uniseriate and formed on sporangiophores arising from medullary filaments and within the cortex . . . . *Elachista*
   Plants pulvinate, epiphytic on *Heterozostera*, cells of long assimilatory filaments with numerous but scattered phaeoplasts; plurilocular sporangia intercalary in sori on long assimilatory filaments.
   . . . . *Halothrix*

Genus *ELACHISTA* Duby 1830: 972, nom. cons. J. Agardh 1848: 7; 1882: 9.

Chapman 1961: 36. Hamel 1935 117, Harvey 1846: 59, Kjellman 1897: 220. Kuckuck 1929: 21, figs 10–14. Lindauer, Chapman & Aiken 1961: 214. Rosenvinge 1935: 19. Sauvageau 1936: 139. Skottsberg 1907: 53; 1953: 537. Svedelius 1911: 162. Takamatsu 1931a: 145. Yamada 1928: 11.

Symphoricoccus Reinke 1889: 17, Kuckuck 1929: 32,
Kjellman 1897: 219.
Poriphillipia Silva 1970: 944.

Thallus epiphytic, pulvinate to globose,
hemispherical or spreading, usually 2–20 mm high
and aggregating in considerable numbers on the
host.

Basal layer of small isodiametric cells, forming
a plate on the host surface, often with short pegs
as extensions of the lower cell wall. Medulla a
filamentous cushion of usually closely packed cells
supporting and completely sheathed by the cortex.
Medullary filaments of non-pigmented, cylindrical
to elongate-ovoid or subglobose cells with
branching from most cells. Rhizoidal filaments
develop from cells of the lower medulla in many
species, and two species (*E. australis* and *E.
lindaueri*) form interweaving, transverse supporting
filaments [Klammenirgane (Kuckuck 1929, p. 19)],
clampirons formed laterally from cells of lower
medulla.

Cortex of short assimilatory filaments and
reproductive organs terminal to the medullary
filaments. Cortical assimilatory filaments
determinate (associated with sporangiophores),
filiform to clavate, straight to arcuate, with 5–20
cylindrical to inflated cells, containing fewer
phaeoplasts than cells of long assimilators. Long
assimilatory filaments (sometimes referred to as
assimilatory hairs) indeterminate (except in *E.
stellaris* Areschoug and *Gonodia marchantiae*
Setchell & Gardner), protruding well beyond the rest
of the thallus with a meristem of short cylindrical
cells, and above with usually elongate, cylindrical
pigmented cells with thick walls.

Unilocular sporangia in the cortex, on short
pedicels, on terminal medullary cells or from the
base of assimilatory filaments, ovoid or pyriform,
with a terminal pore.

Plurilocular sporangia uniseriate, filiform, with
8–48 loculi, either in specialized, corymbose lateral
branches from the outer medulla or laterally from
long assimilatory filaments.

Type species: Elachista scutulata (Smith) Aresch.

A genus of at least twenty species, found on a
wide variety of hosts and known from temperate

and colder seas. Three species occur in Australia,
and two in New Zealand. Sexuality has never been
clearly demonstrated in the life cycle, which, at least
in some species, appears to be direct.

Key to the species of Elachista *in Australia and New
Zealand*

1. Medullary filaments of one kind only; unilocular
   sporangia present; plurilocular sporangia, when
   present, with 8–16 loculi 2
   Medullary filaments of two kinds, unbranched
   filaments which bear the long assimilatory filaments,
   and subdichotomous filaments which bear the cortex;
   unilocular sporangia absent; plurilocular sporangia
   with 16–24(–48) loculi . . . . . . *Elachista orbicularis*

2. Medulla compact, filaments branching from most
   cells, no transverse supporting filaments present;
   cells of long assimilatory filaments at least as wide
   as medullary cells 3

   Medulla loose, with sparsely branched filaments
   producing transverse supporting filaments below;
   cells of long assimilatory filaments narrower than
   medullary cells 4

3. Both unilocular and plurilocular sporangia may be
   present on the one plant, plurilocular sporangia usually
   more common; cortical assimilatory filaments
   cylindrical and plentiful . . . *Elachista claytoniae*

   Unilocular sporangia only present; cortical assimilatory
   filaments clavate but sparse . . *Elachista antarctica*[1]

4. Cells of medullary filaments cylindrical, 7–10 μm
   in diameter; cortical assimilatory filaments filiform,
   wavy, cells narrow, cylindrical and uniform
                                        Elachista australis

   Cells of medullary filaments ovoid-cylindrical,
   20–30 μm in diameter; cortical assimilatory
   filaments clavate and arcuate, upper cells laterally
   inflated
                           . . . . *Elachista lindaueri*

[1] *Elachista antarctica* Skottsberg 1953 has recently been
collected from Macquarie Island (Ricker, pers. comm.)
and may occur on other subantarctic islands south of
Australia and New Zealand. Skottsberg (1953) considered
that this taxon did not produce cortical assimilators.
Cortical assimilators are present but uncommon on
material from Macquarie Island (*Ricker* MA-264,
9.i.1978; ADU A53082).

Fig. 1. A–F *Elachista claytoniae* sp. nov. (ADU, A50809) Holotype. A. Habit, on frond of *Sargassum* sp. B. Upper
medulla and cortex, showing stalked spherical cell among plurilocular sporangia. C. Unilocular and plurilocular
sporangia. D. Filament showing long assimilator and second cortical branches. E. Upper medulla supporting cortex
and long assimilatory filament. F. Lower medulla and base. G–L *Elachista australis* J. Ag. (ADU, A34809) G. Habit,
on *Viphophora*. H. Filament showing narrow transverse filaments from lower nodes, medullary and long assimilatory
filament and cortical branches with cortical assimilators. L. Cortex with unilocular sporangia among cortical
assimilators. J–M *Halothrix ephemeralis* sp. nov. (ADU, A32664, TYPE) J. Habit on *Heterozostera tasmanica*.
K–K2. Filament showing upper medulla, cortical branches with unilocular sporangia, meristem and cells of long
assimilatory filament with sorus of plurilocular sporangia. L. Individual cortical assimilator. M. Medulla and base
of long assimilatory filament.

A
A
10mm

B

C

D

E

F

G
G
10mm

H

I

J
J
10mm

K1

K2

L

M

B-F,H,I,K-M
50μm
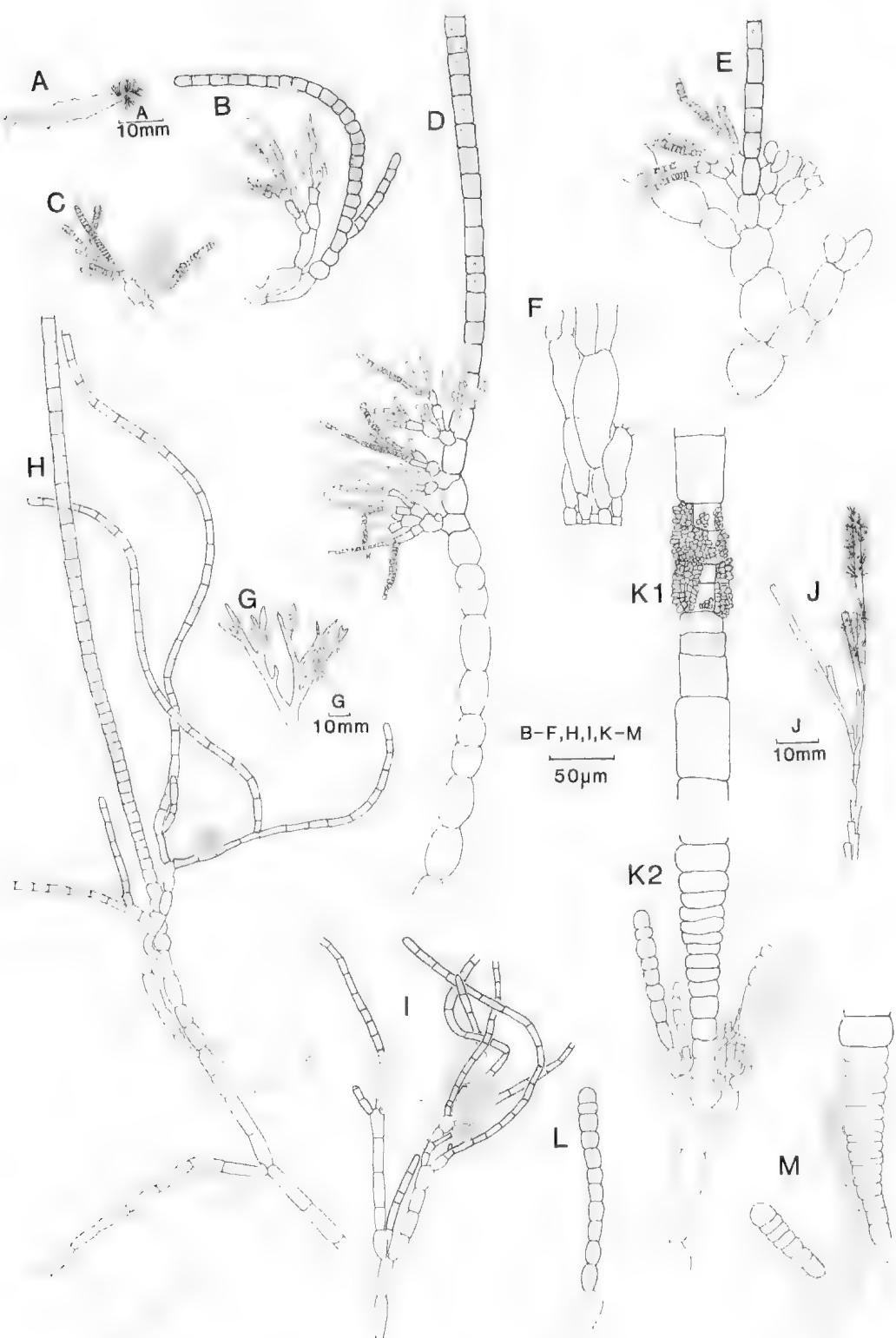
Elachista claytoniae sp. nov.
FIG. 1 A–F

Thallus dark brown, epiphytic on the margins and lamina of the lower leaves of *Sargassum* (Fig. 1A), pulvinate, hemispherical, 0.5–5 mm high.

Basal layer (Fig. 1F) of irregular, isodiametric cells 8–15 μm in diameter, each bearing one medullary cell. Medullary filaments (Fig. 1 D–F) closely packed, subdichotomous, cells pyriform, below grading to subglobose above, non-pigmented, 20–45 μm in diameter, L/B 2.5–4. Cortical assimilatory filaments (Fig. 1B) straight or slightly curved, filiform, with 15–25 pigmented, cylindrical cells 4–6 (–8) in diameter, L/B about (1–) 2–3, borne terminally on branches of medullary filaments together with reproductive structures. Long assimilatory filaments (Fig. 1D) arising from terminal medullary cells and extending to two or three times the length of the rest of the thallus; meristematic zone indistinct; assimilatory cells cylindrical, 12–20 μm in diameter, L/B 1.5–2.5, with numerous discoid phaeoplasts.

Unilocular sporangia ovoid to obpyriform, 23–28 μm in diameter, L/B 2–3, occurring among the plurilocular sporangia (Fig. 1C). Stalked spherical cells, among the young plurilocular sporangia, have been observed in the isotype MELU 20520, and the holotype ADUA50809, but zooid masses were not observed in such organs (Fig. 1B), and their function is unknown.

Plurilocular sporangia (Fig. 1D, E) are grouped on corymbose branches on medullary filaments or immediately below the meristematic region of long assimilatory filaments, filiform, uniseriate, with occasional oblique cross walls and 12–16(–24) loculi, 5–8 μm in diameter, opening by a terminal pore, outer wall persistent.

Diagnosis: Thallus pulvinatus, 0.5–5 mm alt; fila medullae conferta, cum cellulis aut pyriformibus inferne aut subglobosis superne; fila assimilata corticata aut stricta aut leviter arcuata, filiforma cum 15–20 cellulis; fila assimilata longissima cum cellulis teretibus, 15–20 μm diametro, L/B 1.5–2.5; sporangia unilocularia ob pyriforma; sporangia plurilocularia uniseriata, filiforma in sporangiophoribus corymbosis aut ex medulla superne aut ex filis longissimis.

Holotype: ADU, A50809 (*Clayton*, 21.ix.1970). Isotype MELU, 20520.

Type locality: Ocean Beach, Sorrento, Victoria.

Distribution: Port Phillip Heads, Vic.

Hosts: Sargassum spp.

Specimens examined: Queenscliff, Vic. (*Clayton*, 6.ix. 1969; ADU, A50331); Sorrento, Vic. (*Clayton*, 4.ix.1971; MELU, 21207); Point Nepean, Vic. (*Clayton*, 4.v.1969; ADU, A50332).

The specific epithet, "claytoniae", is chosen to honour the collector Dr Margaret Clayton, and her distinguished work on Phaeophyceae in southern Australia.

Elachista mollis Takamatsu 1938a Fig. 5 is similar in form to *E. claytoniae* in that the cortical branches support the sporangiophores, but it has clavate rather than filiform cortical assimilatory filaments. *E. globosa* Takamatsu 1938a and *E. zosterae* Noda & Kitami 1971 also are similar to *E. secundata* in general morphology. *E. globosa* has globose cells throughout the medulla, and *E. zosterae* is somewhat like *Halothrix* species below the cortex.

Elachista australis J. Agardh 1882: 13.
De Toni 1895: 440. Guiler 1952: 78. Lucas 1909: 19; 1913: 58; 1929: 14. *Philippia australis* (J. Ag.) Kuckuck ex Oltmanns 1922: 34, fig. 327. Kuckuck 1929: 19, fig. 8. (Non *Philippia* Klotzsch 1834: 354). *Philippiella australis* (J. Ag.) Silva 1959: 63. Lindauer, Chapman & Aiken 1961: 215, fig. 42. Womersley 1967: 229. (Non *Philippiella* Spegazzini 1896: 566). *Portphillipia australis* (J. Ag.) Silva 1970: 944.

FIG. 1, G–I

Thallus medium brown, epiphytic on upper ramuli of species of *Xiphophora* (Fig. 1G), compact, globose to pulvinate, 0.5–5.0 mm high.

Basal layer restricted in area, with a plate of small isodiametric cells forming pegs into host surface and supporting the medullary filaments. Medulla filamentous (Fig. 1H), cells cylindrical, weakly pigmented, 7–15 μm in diameter, L/B 5–8. Branching of medullary filaments at intervals, with five or more cells in each internode, and often two laterals arising at each node; in lower medulla one or more lateral filaments may form interweaving transverse supporting filaments, while in the upper medulla lateral branches usually give rise to cortical assimilatory filaments and associated unilocular sporangia, with the main axis of the medullary filament continuing as a long assimilatory filament. Cells of transverse supporting filaments 4.5–5.5 μm in diameter, L/B 5–7.

Cortical assimilatory filaments (Fig. 1 H–I) flexible, sinuous, of 25–30 cells at maturity, 4–7 μm in diameter, L/B 3–7. Long assimilatory filaments broader and extending beyond the thallus by 2–5 times; cells short with numerous small phaeoplasts, 10–12 um in diameter, L/B 1–2.

Unilocular sporangia (Fig. 1I) borne on a one celled pedicel or sessile on lower cells of cortex, ovoid to cylindrical with a terminal pore, 45–60 μm long and 20–50 μm in diameter.

Plurilocular sporangia unknown.

Type locality: Port Phillip Heads, Victoria (*Harvey*, Alg. Aust. Exsicc. 101 as *Leathesia* sp. nov.?).

Type: Herb. Agardh, LD (45972).

Distribution: Apollo Bay to Port Phillip Heads, Victoria, the north and east coasts of Tasmania, and Stewart I., New Zealand.

Host range: Xiphophora chondrophylla and *X. gladiata.*

Specimens examined: Port Phillip Heads, Vic (*Harvey,* Alg. Aust. Exsicc, 101 E; ADU, A18551); Apollo Bay, Vic. (*Womersley,* 10.xii.1969; ADU, A34809); Point Lonsdale, Vic. (*Skinner,* 4.i.1978; ADU, A49067); Ulverstone, Tas. (*Gordon,* 18.i.1966; ADU, A30107); Bellerive, Derwent R., Tas. (*Rodway,* Oct. 1909; ADU, A5815); Boat Harbour Point, N Tas. (*Womersley,* 16.x.1982; ADU, A55750); Tesselated Pavements, Eaglehawk Neck, Tas. (*Parsons & Womersley* 30.x.1982; ADU, A53981 CHR, 399502); Ringaringa, Stewart I., New Zealand (*Womersley,* 4.i.1966; ADU, A29810).

Elachista australis and *E. lindaueri* Chapman are distinctive species. Both show a loose and extensive medulla with transverse supporting filaments and the development of a subcortex by concentration of lateral branches in the upper medulla to support the cortical assimilators. *E. lindaueri* (see below) has larger cells throughout; the medullary cells are inflated rather than cylindrical as in *E. australis,* and the cortical assimilators are arcuate rather than sinuous, with the upper cells inflated laterally. The presence of the transverse supporting filaments was used by Kuckuck (Kuckuck in Oltmanns 1922, Kuckuck 1929) to distinguish the genus *Philippia* from *Elachista.* There are several other species of *Elachista* e.g. *E. mollis, E. secundata* and *E. globosa* Takamatsu 1938a, which show a concentration of branching in the upper medulla, although none of these taxa produce transverse supporting filaments. The retention of the genus *Periphillipia* Silva (= *Philippia* Kuckuck non Klotzsch) with the inclusion of *E. australis* and *E. lindaueri,* does not seem warranted, and *P. australis* is here returned to *Elachista.*

Elachista lindaueri Chapman 1961; 16, fig. 2.
Lindauer, Chapman and Aiken 1961: 215.

FIG. 2 A–D

Thallus yellow-brown, globose to pulvinate, epiphytic on *Xiphophora chondrophylla.*

Basal layer contracted to a very small disk. Medullary filaments (Fig. 2A, B) very long and sparsely branched, cells inflated-cylindrical, 20–30 μm in diameter, L/B 2–3; lower laterals forming rhizoid-like, branched, transverse supporting filaments with often more than one from the same node; 1–3 upper branches (Fig. 2A, C, D) from one node, forming a subcortex supporting the cortical assimilators and unilocular sporangia. Cortical assimilatory filaments slightly clavate, arcuate, the upper cells laterally expanded and deltoid. Long assimilatory filaments (Fig. 2A) usually terminal to the main axis of a medullary filament, with a

meristem at or just above the level of the cortex; mature cells cylindrical, 12–20 μm in diameter, L/B 1–1.5.

Unilocular sporangia sessile ovoid to pyriform, 30–50 μm in length and 12–18 μm in diameter, L/B 3–6, borne laterally on lower cortical cells. Plurilocular sporangia unknown?

Type locality: Bay of Islands, New Zealand (Lindauer, 6.xi.1937).

Type: AKU (Herb. Lindauer No. 29).

Specimen examined: Isotype (ADU, A4573) and Long Beach, Russel, New Zealand, lower eulittoral pools (*Womersley,* 28.x.1969; ADU, A35069).

Distribution: throughout New Zealand.

Chapman's (1961) description makes no mention of the transverse supporting filaments, and is incomplete in the description of branching in the medulla. His description of "plurilocular gametangia formed by modification of ends of assimilators", without a figure, is unsubstantiated in the specimens examined.

Elachista orbicularis (Ohta) Skinner 1983; 98, Figs 1–3.

Gonodia orbicularis Ohta 1973: 21, fig. 11. Noda 1975: 101. fig. 12.

No further data have been obtained to add to the species description of Skinner (1983).

Type Locality: Tappi, Aomori Pref., Japan (Ohta, 1.i.1970).

Type: (Ohta 133) in Herbarium, Niigata University.

Distribution: Japan, and southern Australia (from Rottnest Island, W. Aust. to Port Hacking, New South Wales). This species is present on its host throughout the year.

Hosts: Undaria species in Japan, *Ecklonia radiata* (C. Agardh) J. Agardh in Australia.

The two most closely related taxa to *Elachista orbicularis* are *E. nigra* Takamatsu 1938a, and *Gonodia fusiformis* Noda in Honda 1969 nom. nud. (a species of *Elachista*) both endemic to Japan. While the other species show the formation of some laterals from those medullary filaments which support the long assimilatory filaments, *E. orbicularis* develops such laterals only very occasionally, and then from the lower-most cells.

Genus *HALOTHRIX* Reinke 1889: 49.

Hamel 1935: 126. Kuckuck 1929: 26. figs 15–17. Rosenvinge 1935: 37. Takamatsu 1938b: 181. Yamada 1928: 513. Yendo 1909: 123

Thallus pulvinate, hemispherical, loosely compacted, up to 2 cm high, epiphytic on Zosteraceae. Individual plants may be densely clustered, giving the appearance of one plant.

Basal layer a central disc of isodiametric cells with, at the margins, a rhizoidal system from small isodiametric cells in the lowermost medulla.

A–D
50μm
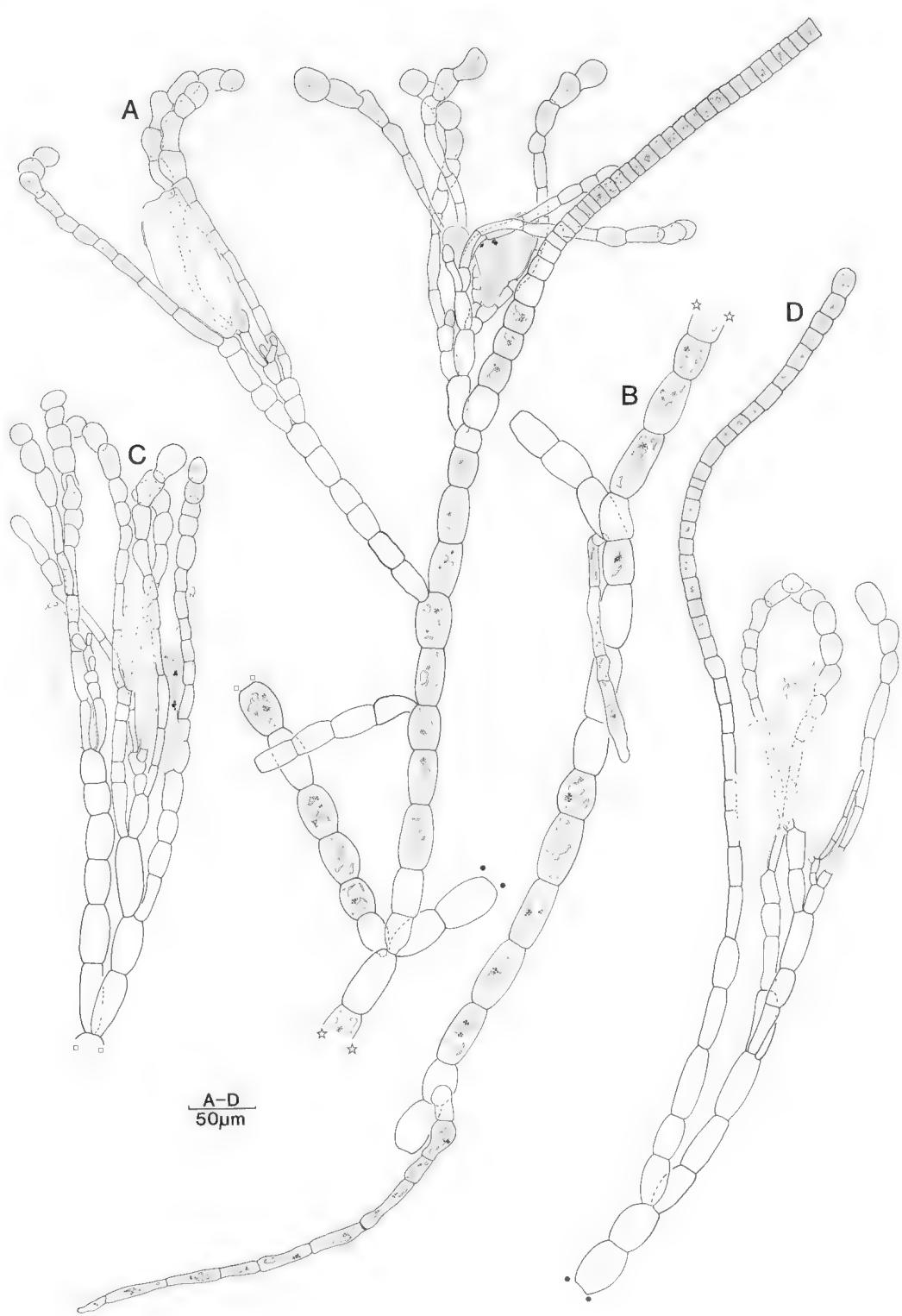
Medullary filaments of pyriform or subglobose non-pigmented cells, with branching confined mainly to upper cells. Cortical assimilatory filaments clavate, arcuate or straight, of a few ovoid or cylindrical cells, formed immediately below the meristematic zone of the long assimilatory filaments, on lateral medullary cells. Long assimilatory filaments narrower basally, extending in length many times beyond the rest of the thallus, with short cells (L/B about 1) with numerous scattered phaeoplasts.

Unilocular sporangia arising from upper medullary cells, ovoid-cylindrical or urceolate, with a terminal pore and plug.

Plurilocular sporangia in sori on anticlinally divided groups of cells in upper parts of long assimilatory filaments.

Type species: H. lumbricalis (Kütz.) Reinke.

A genus of five described species, *H. lumbricalis* from the north Atlantic and Baltic, and four species from Japan. An additional new species is here described from southern Australia. The principal difference between this genus and *Elachista* is the specialized plurilocular sporangia on the surface of the long assimilatory filaments in *Halothrix*. While *E. stelloris* forms plurilocular organs on long assimilatory filaments, they do not involve the prior subdivision of the whole mother cell as in *Halothrix*. Pedersen (1979) has shown that *Halothrix lumbricalis* has a simple direct life cycle. In a recent paper Pedersen (1984) has suggested the inclusion of *Halothrix* in the Giraudiaceae on the basis of similarities in morphogenesis. However, the concentration of branches in the medulla immediately below the meristem in *Halothrix* is also seen in various species of *Elachista*, notably in *E. mollis*, *E. claytoniae*, *E. globosa* and *E. zosterae*. More importantly, the development of the photosynthetic part of the *Giraudia* thallus, above the meristem, involves an orderly sequence of periclinal divisions of the cells of each whorl or tier (Skinner & Womersley, 1984), which is not seen in *Halothrix*. *Myriotrichia* species show possibly closer parallels to *Giraudia*, as the axis of the thallus in that genus undergoes periclinal division of assimilatory cells before the production of unilocular and plurilocular sporangia (Kuckuck, 1899).

Halothrix ephemeralis sp. nov.
FIG. 1 J–M

Thallus brown, epiphytic on *Heterozostera tasmanica* leaf blades (Fig. 1J), often so numerous as to cover most of the blades; pulvinate; loosely compacted, 5–15 mm high.

Basal plate of small isodiametric cells 10–15 μm in diameter, adnate to host surface. Medullary filaments (Fig. 1 K–M) with 3 or 4 lower tapering cells 20–25 μm in diameter, L/B 2.5–4, infrequently branching, and 2 to 4 upper subglobose cells 20–30 μm in diameter, L/B about 1, branching subdichotomously. Cortical assimilatory filaments straight, of 8–15 slightly inflated cells, grading upwards from cylindrical to subglobose, 10–15 μm in diameter, L/B 1–1.5 (Fig. 1 K$_2$, L). Long assimilatory filaments (Fig. K$_{1\&2}$, M) many times longer than the rest of the thallus, cells increasing in diameter upwards, short but broad, upper photosynthetic cells cylindrical, 30–50 μm in diameter, L/B 0.5–2.

Unilocular sporangia (Fig. 1K$_2$) cylindrical, with a terminal domed plug and pore and tapering basally, 15–30 μm in diameter, usually paired on lateral medullary branches arising immediately below the meristem of a long assimilatory filament together with cortical assimilatory filaments, maturing sequentially.

Plurilocular sporangia (Fig. 1K$_1$) in intercalary sori borne on 2–6 modified cells of long assimilatory filaments; the soral mother cell undergoing two or three anticlinal divisions, with individual sporangia (some with a basal cell) arising from periclinal divisions of these secondary cells; often present on plants before unilocular sporangia develop.

Diagnosis: Thallus usque ad *Halothrix ambigua*, sed filis assimilatis corticatis strictis filiformibusque nec arcuatis cum cellulis inflatis, utque sporangiis unilocularis pyriformibus, sporangiis plurilocularis intercalaribus ab cellulis fili longissimi.

Type locality: Aldinga reef, S. Aust., in shallow pools and gutters especially near the southern seaward margin of the platform.

Holotype: ADU, 32664 (*Womersley*, 29.viii.1968).

Distribution: Only known from type locality (Aldinga reef, S. Aust.) [*Skinner* 14.ix.1977; ADU, A48249 and A48250; 15.ix.1978; ADU, A49553). There are two specimens, MELU, 21072 and 21143, on *Heterozostera* from localities in the Port Phillip area of Victoria, which are labelled *H. lumbricalis*, but the plants are very small, not very fertile and not identifiable beyond genus.

Host: Heterozostera tasmanica.

Specimens examined: As above.

The macrothallial stage is present for a very short season, hence the specific epithet. It has been found only during August and September, for a period of less than six weeks. This species differs from *H.*

Fig. 1. *Elachista indaueri* Chapman (ADU, A35069). A to D all part of one filamentous system. A. Upper medulla with cortex and main long assimilator. B. Lower medulla with transverse filaments. C,D. Medullary and cortical side-branch systems.

ambigua Yamada (based on a specimen from Muroran, Hokkaido, Japan (*Kurogi*, 8.v.1978; ADU, A49376) by possessing straight, not curved, slightly medianly inflated cortical filaments, and an almost cylindrical, not ovoid, unilocular sporangium. The differences between this species and *H. lumbricalis* are the possession of unilocular sporangia, the absence of inflated cells towards the top of the cortical filaments, and the discrete basal layer rather than a rhizoidal system. *H. ephemeralis* is also similar to *H. tortuosa* Takamatsu, which also has straight cortical assimilatory filaments but a less clearly defined branch system at the cortical-medullary boundary than *H. ephemeralis*.

Discussion

The southern Australian and New Zealand regions have four species of *Elachista* and one of *Halothrix*. One other species, *E. antarctica*, is confined to subantarctic islands such as Macquarie Island. *E. claytoniae* from Port Phillip Heads, Victoria, and the single species of *Halothrix*, *H. emphemeralis* from Aldinga reef in South Australia, appear to have restricted distributions, although the plants may be quite common within that distribution for short periods of the year. *Elachista australis*, although sometimes locally common in the summer months, is not often collected, and does not appear to be as widespread as its two host plants, *Xiphophora chondrophylla* and *X. gladiata*, the former confined to south eastern Australia and the latter to Tasmania.

On the other hand, *Elachista orbicularis* has a wide distribution in Australia—from Rottnest Island in W.A. to Sydney in N.S.W.—and occurs at most times of the year, usually in large numbers on the host. As the first record of this alga in Australia came from Port Noarlunga, S.A. in 1975, it is quite possible that the species is a recent introduction from Japan. *E. orbicularis* is sometimes associated with epiphytic ectocarpoids which are frequently seen on senescent plants of *Ecklonia radiata*, and may thus have been overlooked. The recorded localities are rather disjunct; there are no records for Victoria, and although the host is usually found as a major component of the sublittoral on rocky coasts throughout South Australia, plants of *Ecklonia radiata* infected with *Elachista orbicularis* have not been found in South Australia outside of the rather narrow range of Gulf St Vincent and Encounter Bay.

Portphillipia is here synonymised with *Elachista*. While *E. australis* and *E. lindaueri* are clearly highly specialized members of the genus, the production of transverse supporting filaments hardly justifies the separation of the two species into a distinct genus. These two species are the most structurally evolved of one developmental line within *Elachista*. No such generic separation has been suggested for the other divergent group of species which includes *E. intermedia* Crouan & Crouan, *E. nigra* and *E. orbicularis*, although they also show specialization of form and function of cells and filaments of the medullary tissues.

Interspecific relationships in *Elachista*

On the basis of relative complexity of vegetative morphology and characteristics of sporangia, the genus *Elachista* may be separated into three sections. The comparison of species presented here has been made largely on published descriptions and illustrations together with examination of herbarium material of a few of the species.

As will be seen from the lists of taxa included in the sections of the genus, no attempt is made to change the nomenclature of taxa not recorded in southern Australia. The separation of *Elachista* Duby (which produces two kinds of assimilatory filaments) from *Myriactula* Kuntze ($\equiv$ *Myriactis* sensu Kützing, = *Gonodia* Nieuwland 1917), which produces one determinate kind of assimilatory filament and indeterminate phaeophycean hairs, dates back to Kjellman (1890). Pedersen (1979) interpreted the hair-like filaments produced by crowded plants of *E. lubrica* as modified long assimilators, not as hairs as Jaasund (1960) had in separating *E. lubrica* from *Elachista* and including it in *Myriactula*. Many of the northern Pacific taxa which have been included in *Elachista*, or excluded from it, on the basis of descriptions and illustrations noting presence or absence of hairs, should have their nomenclatural status reviewed in the light of the two opinions as to the nature of those hairs.

Section 1: Plants partly endophytic, with a basal system of rhizoids, penetrating beyond the host epidermis; medulla compact, filaments diffusely branched; cortical assimilatory filaments absent, but long assimilatory filaments present; unilocular sporangia present; plurilocular sporangia both in corymbose groups at the base of long assimilators and laterally from cells of long assimilators.

Taxa included: Elachista stellaris Areschoug. Wanders *et al.* 1972.

Section 2: Plants epiphytic, with discrete basal layer often with peg-like projections from basal cells and rhizoids from lower medullary cells; medulla filamentous, with one kind of filament, branching irregular; cortical assimilators (paraphyses) present in most species; unilocular sporangia usually present; plurilocular sporangia, when present, in corymbose groups in the cortex, individual sporangia with (6-)8-16 loculi (*E. scutulata* may have 16-24 loculi). In *E. lubrica* Ruprecht,

plurilocular sporangia may also form laterally to cells of long assimilators (although the origin and function of these structures is interpreted otherwise by Pedersen (1979)). Pedersen (1984) provides strong evidence of conspecifity of *E. lubrica* and *E. fucicola*. There are two subsections.

Subsection 2a: Medullary filaments close packed, branching from most cells, or with short internodes of 10 or fewer cells, with concentration of branching in upper medullary filaments (to form a subcortex) in some species; plurilocular sporangia present in many species. Taxa included: *Gonodia marchantiae* Setchell & Gardner 1924; *Elachista coccophorae* Takamatsu 1938a, Noda 1969; *E. antarctica* Skottsberg 1953; *E. lubrica* Ruprecht, Kuckuck 1929; *E. fucicola* (Velley) Areschoug, Hauck 1885; *E. meridionalis* Skottsberg 1907; *E. scutulata* (Smith) Areschoug, Kjellman 1897, Hamel 1935; *E. flaccida* (Dillwyn) Areschoug, Hamel 1935, Takamatsu 1938a; *E. globosa* Takamatsu 1938a, Noda 1969; *E. claytoniae* Skinner sp. nov.; *Gonodia johnstonii* Setchell & Gardner 1924; *E. zosterae* Noda in Noda & Kitami 1971; *E. mollis* Takamatsu 1938a.

Subsection 2b: Medullary filaments loose, branching at intervals of (5–)10–15 cells, with upper branches forming a subcortex to support the cortical assimilators and unilocular sporangia, and lower branches of the medullary filaments modified to interweaving transverse supporting filaments; plurilocular sporangia unknown.

Taxa included: Elachista lindaueri Chapman 1961; *E. australis* J. Agardh 1882, Kuckuck 1929.

Section 3: Plants epiphytic with discrete basal layer often with peglike projections from basal cells and rhizoids from lower medullary filaments; two morphologically distinct kinds of medullary filaments, one with broader cylindrical to ovoid cells, supporting the long assimilatory filaments, and the other of narrower elongate-ovoid cells, branching throughout, supporting the cortical assimilatory filaments and reproductive organs; unilocular sporangia present in some species; plurilocular sporangia in corymbose groups,

individual sporangia with (16–)24–48 loculi. The second kind of medullary filament may arise laterally from the first kind of medullary filament or separately from the basal cells.

Taxa included: Elachista nigra Takamatsu 1938a; *E. intermedia* Crouan & Crouan (= *E. neglecta* Kuckuck 1929) Sauvageau 1936; *E. tenuis* Yamada 1928, Takamatsu 1938a (incl. f. *pacifica*), Noda 1969, 1974; *Myriactula sargassi* (Yendo) Feldmann 1943, Noda 1964[2]; *E. orbicularis* (Ohta) Skinner 1983, Noda 1975, Ohta 1973; *Gonodia fusiformis* Noda in Honda 1969, nom. nud.

Taxa excluded from *Elachista*

Elachista ramosa Skottsberg 1907 = *Gononema ramosa* (Skottsberg) Skottsberg 1921; *E. rosarioides* Skottsberg 1921 = *Myriactula rosarioides* (Skottsberg) Skottsberg 1953; *E. pusilla* Skottsberg 1921 = *Myriactula pusilla* (Skottsberg) Skottsberg 1953. The following six taxa are described or figured as having true phaeophycean hairs and should thus be included in genera in the Leathesiaceae: *E. minutissima* Taylor 1928, 1960; *E. crassa* Takamatsu 1938a; *E. taeniaeformis* Yamada 1928; *E. vellosa* Takamatsu 1938a; *E. sadoensis* Noda 1969; *E. sargassicola* Noda 1969.

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[2]Yendo (1920) describes this taxon as having occasional hairs, but Noda's (1964) description and illustrations are without hairs. There may be two taxa involved here

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THE SPATANGOID ECHINOID LINTHIA FROM THE LATE EOCENE OF SOUTHERN AUSTRALIA

BY K. J. MCNAMARA

Summary

Five specimens, one from the late Eocene Tortachilla Limestone in South Australia, and four from the Pallinup Siltstone in south-western Australia, are described as a new species, Linthia pulchra sp.nov. The absence of a lateroanal fasciole is not thought to be of sufficient importance to warrant placing this species in any other genus other than Linthia. The concept of the genus Linthia is emended to include forms both with and without a lateroanal fasciole.

THE SPATANGOID ECHINOID *LINTHIA* FROM THE LATE EOCENE OF SOUTHERN AUSTRALIA

by K. J. McNamara*

Summary

McNamara, K. J. (1985) The spatangoid echinoid *Linthia* from the Late Eocene of southern Australia. *Trans. R. Soc. S. Aust.* 109(4), 161-165, 29 November, 1985.

Five specimens, one from the Late Eocene Tortachilla Limestone in South Australia, and four from the Pallinup Siltstone in south-western Australia, are described as a new species, *Linthia pulchra* sp. nov. The absence of a lateroanal fasciole is not thought to be of sufficient importance to warrant placing this species in any genus other than *Linthia*. The concept of the genus *Linthia* is emended to include forms both with and without a lateroanal fasciole.

Key Words: Spatangoid echinoid, *Linthia*, Eocene, new species, southern Australia.

Introduction

Within the Tertiary sequence of southern Australia the rich spatangoid echinoid fauna has yielded a number of forms which, at sometime or other, have been assigned to the genus *Linthia*. Tate (1885) described *Linthia antiaustralis* from the Early Miocene of the Murray River cliffs; H. L. Clark (1946) placed *Megalaster compressa* in *Linthia*; and Pritchard (1908) placed two of McCoy's (1882) species, *Pericosmus nelsoni* and *Pericosmus gigas* in *Linthia*, along with a new species, *L. mooraboolensis*. However, as discussed below, none of these species belong in the genus *Linthia*. Consequently, this common, cosmopolitan, Tertiary genus has not previously been described from Australia.

It is the aim of this paper to describe what is not only the largest known spatangoid echinoid from the Late Eocene Tortachilla Limestone in South Australia and the Pallinup Siltstone in Western Australia, but also to record the presence of *Linthia* in the Australian Tertiary.

The material upon which this paper is based consists of a single specimen from the Tortachilla Limestone in South Australia and four from the Pallinup Siltstone in Western Australia. Although the Tortachilla Limestone specimen does not have its adoral surface preserved, much of its aboral surface is in an excellent state of preservation. Three of the specimens from the Pallinup Siltstone are preserved only as internal moulds, but with both aboral and adoral surfaces preserved. The other specimen is poorly preserved and consists of an external and internal mould. Sufficient details are preserved in the five specimens to be confident that they are conspecific and represent a hitherto undescribed taxon.

Measurements on the specimens were made with a vernier calliper to an accuracy of 0.1 mm. A number of parameters are expressed as percentages of maximum test length (%TL). Specimens are housed in the collections of the Museum of Victoria (NMV); Western Australian Museum (WAM) and Geological Survey of Western Australia (GSWA).

Stratigraphy

The Tortachilla Limestone is a yellow-brown, green and grey bioclastic limestone which in outcrop in the Willunga Embayment of the St Vincent Basin, South Australia, attains a maximum thickness of 2 m in cliffs at the south end of Maslin Beach (Reynolds 1953; Cooper 1979). It is early Late Eocene in age (Ludbrook 1963; McGowran 1978; Lindsay 1985). It contains a rich marine invertebrate fauna, predominant amongst which are the echinoids. Most forms from this unit have been described, including the following: *Stereocidaris cudmorei* Philip, 1964; *S. fosteri* Philip, 1964; *S. inermis* Philip, 1964; *S. hispida* Philip, 1964; *S. intricata* Philip, 1964; *Salenidia tertiaria* (Tate, 1877) (see Philip 1965); *Ortholophus bittneri* Philip, 1969; *Tatechinus nudus* Philip, 1969; *Fibularia gregata* Tate, 1885; *Echinolampas posterocrassa* Gregory, 1890 (see McNamara & Philip 1980a); *Apatopygus vincentinus* (Tate, 1891); *Australanthus longianus* (Gregory, 1890); *Pisolampas concinna* Philip, 1963; *Giraliaster tertiarius* (Gregory, 1890); *G. bellissae* Foster & Philip, 1978; *Gillechinus cudmorei* Fell, 1964 (see McNamara *et al.* in press); *Hemiaster (Bolbaster)* sp. nov. (McNamara, in press); *Prenaster aldingensis* Hall, 1907; *Protenaster preaustralis* McNamara, 1985; *Schizaster (Paraster) tatei* McNamara & Philip, 1980b.

The Pallinup Siltstone, a member of the Werillup Formation within the Plantagenet Group, is a siltstone of spongolite which occurs discontinuously along the southern coast of Western Australia (see Darragh & Kendrick 1980, Fig. 1). This richly fossiliferous unit is considered to have been deposited in a shallow shelf environment (Darragh

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& Kendrick 1980). Echinoids form a major part of the marine invertebrate fauna, but remain essentially undescribed. *Gillechinus cudmorei* has been recorded from the unit (McNamara *et al.* in press). Other forms present include *Schizaster (Paraster)* sp. nov.; *Prenaster aldingensis; Giraliaster bellissae;* and ?*Pericosmus* sp. Locally spines of regular echinoids are common. On the basis of the bivalve fauna, Darragh & Kendrick (1980) considered that the Pallinup Siltstone correlates with the Blanche Point Formation, Tortachilla Limestone and Browns Creek Clay. These units cover the planktonic foraminiferal zones P15-16 (Ludbrook 1973; McGowran 1978).

SYSTEMATIC PALAEONTOLOGY

Order Spatangoida Claus, 1876
Family Schizasteridae Lambert, 1905
Genus *Linthia* Desor, 1853

Emended diagnosis: Test commonly small, heart-shaped, anterior ambulacrum not petaloid, depressed with groove at margin; apical system ethmolytic, subcentral with 4 genital pores; petals of almost equal length; peripetalous fasciole sharply indented between petals; lateroanal fasciole present or absent.

Remarks: Kier (1984) has recently provided a diagnosis of *Linthia.* The southern Australian Late Eocene form accords well with this diagnosis in its possession of a depressed ambulacrum III with prominent anterior notch; ethmolytic apical system with four genital pores; petals of similar length; and indented peripetalous fasciole. However, Kier (1984) diagnosed the genus as possessing a lateroanal fasciole. Although the Schizasteridae are generally typified by their possession of both a peripetalous and lateroanal fasciole (Fischer 1966), in some genera the lateroanal fasciole is not always entire or present in all species or in all specimens of a single species (Mortensen 1951).

McNamara & Philip (1980b) have discussed the problems involved in using the characters of the fascioles in the supraspecific classification of the Schizasteridae. For example, the lateroanal fasciole may be present or absent, as in *Paraster;* only present in juveniles, as in *Abatus;* reduced or lost, as in *Brisaster;* incomplete, as in *Tripylus* and *Parabrissus;* or absent altogether, as in *Kina.*

Although species of *Linthia* typically possess a lateroanal fasciole, examples have been described in which it may be incomplete in some individuals, or missing entirely from an entire population. Gregory (1906) described *Linthia oblonga* (d'Orbigny, 1854) from the Cenomanian-Turonian of Sinai and Egypt. In this species the peripetalous fasciole is invariably preserved, but the lateroanal fasciole is either absent or present only as obscure

traces. This absence is not a function of preservation as the tubercles and peripetalous fascioles are well preserved. Newton (1904) similarly observed this variability in *L. oblonga* from Sinai.

A similar situation is found in a form described by Bather (1904) from north-west Nigeria as *Hemiaster sudanensis.* This species is ethmolytic and in appearance belongs more appropriately in *Linthia.* This was also the view of Lambert & Thiéry (1925). Bather noted how specimens from certain localities show the lateroanal fasciole (for example Bather 1904, Pl. 11, Fig. 13), whilst from the other localities it is clearly absent (Bather 1904, Pl. 11, Fig. 7).

Consequently the revised diagnosis of *Linthia* presented above takes into account the ephemeral nature of the lateroanal fasciole. Although much of the test of the Tortachilla Limestone specimen described herein is very well preserved, the lateral parts of the test unfortunately suffer from extensive post-mortem encrustations of bryozoans. Consequently only one small portion of the lateral part of the test, where the lateroanal fasciole would be expected to be, is well enough preserved to indicate whether or not this fasciole is present. Close examination in this region near to the junction with the peripetalous fasciole, has revealed the absence of a lateroanal fasciole. The only specimen from the Pallinup Siltstone which shows part of the external surface (WAM 66.637) is not well enough preserved to provide corroborative evidence one way or the other. In all other aspects this species resembles a typical *Linthia,* within which genus it is therefore placed.

Linthia pulchra sp. nov.
FIG. 1

Material: Holotype, NMV P20455, from the Late Eocene Tortachilla Limestone, southern Maslin Beach, South Australia. Paratypes GSWA F5828, from the Late Eocene Pallinup Siltstone, at Stokes Brick Pit, Albany, Western Australia; WAM 66.637 from the Pallinup Siltstone at Bremer Bay, Western Australia; WAM 85.710, 85.711 from the Pallinup Siltstone near Albany, Western Australia.

Diagnosis: Test relatively narrow, maximum width anterior of centre; apical system slightly anterior of centre; ambulacrum III long, moderately depressed; anterior notch well impressed and broad; petals long and relatively narrow.

Description: Test reaching a maximum length of 80 mm; relatively narrow, width being 90.5% TL in both undistorted specimens (NMV P20455 and GSWA F5828); maximum width about one-third TL from anterior margin; height 50-54% TL, highest point slightly posterior of centre in weakly developed keel; posteriorly truncated. Anterior
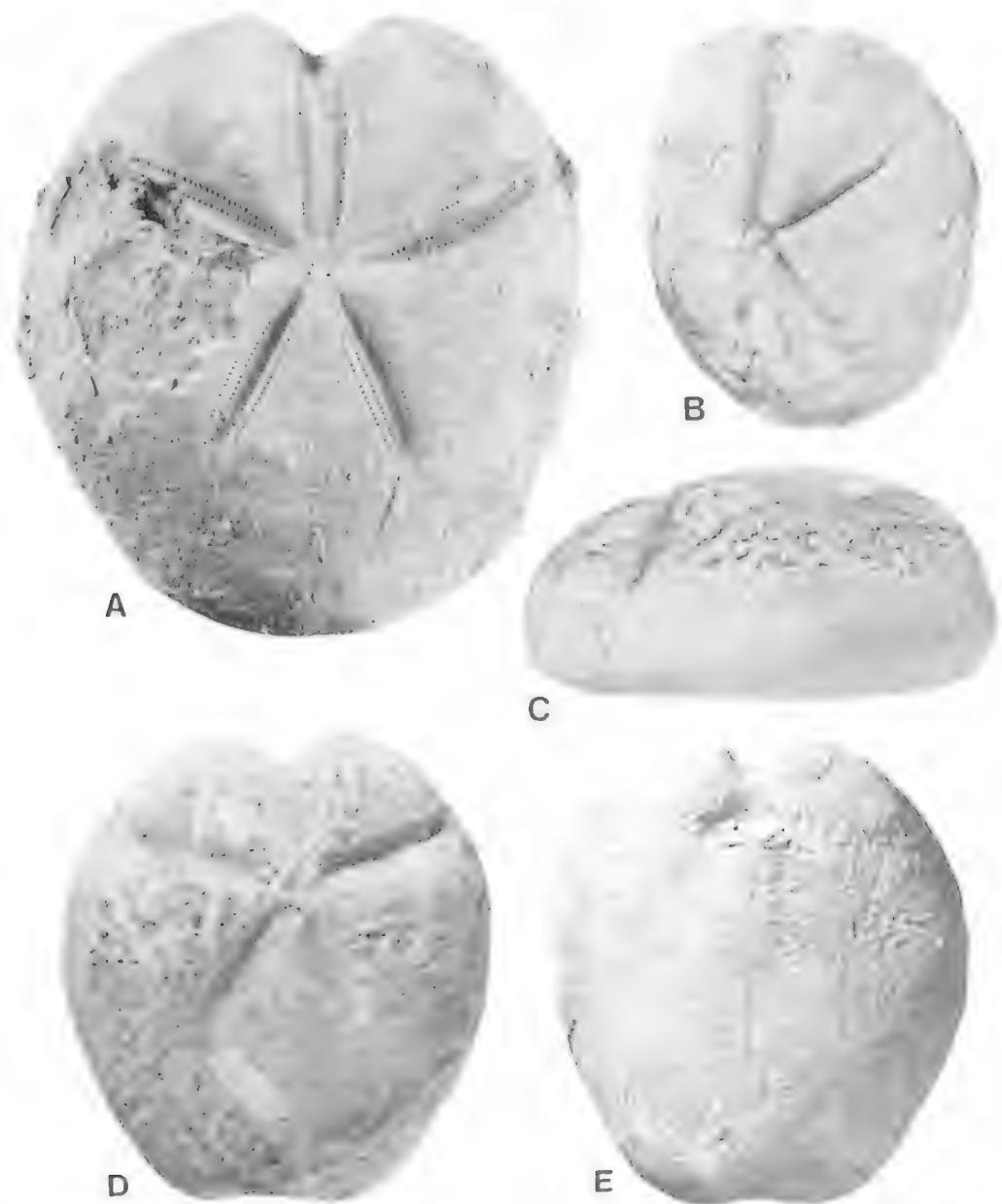
Fig. 1. *Linthia pulchra* sp. nov.; A, NMV P20455, holotype, aboral view, from the Late Eocene Tortachilla Limestone at Maslin Beach, South Australia; B, WAM 66.637, paratype, aboral view of latex cast of external mould, from the late Eocene Pallinup Siltstone, Bremer Bay, Western Australia; GSWA F5828, paratype, C, lateral view, D, aboral view, E, adoral view, from the Late Eocene Pallinup Siltstone, Albany, Western Australia; all ×1.

notch deep (8.7% TL) and broad (11.3% TL). Apical system ethmolytic with four genital pores, anterior pair being smaller than posterior pair; moderately depressed and situated 39% TL from anterior ambitus; madreporite long. Ambulacrum III depressed and broad; bearing large number (42) of pore pairs; within each pair pores aligned about 15° to transverse line and separated from each other

by a prominent, swollen interporal partition. Flanks of ambulacrum III bear larger tubercles than found anywhere else on test. Floor of ambulacrum III covered by dense array of miliary tubercles. Petals deep; anterior pair diverge at about 130° and are 41% TL in length, bearing up to 44 slightly conjugate pore pairs, outer pore of which is slit-like and inner nearly circular. Posterior petals

diverge at about 60° and are 31% TL long in holotype, 28% TL long in paratype, bearing up to 38 pore pairs which are similar in form to those of the anterior petals. Posterior petals slightly narrower than anterior pair, being 7% TL compared with 8% TL. Peripetalous fasciole slightly indented in interambulacra 2, 3, and 5; strongly indented in interambulacra 1 and 4.

Adoral surface slightly convex. Peristome anteriorly situated, posterior margin being situated 20% TL from anterior ambitus; semicircular in form, width 16.5% TL; slightly sunken. Labrum does not project anteriorly; constricted at one-quarter length from anterior, flaring strongly posteriorly. Plastron nearly flat; length 56% TL; width 40% TL. Periproct slightly sunken; dimensions unknown.

Discussion: Although the specimen from the Tortachilla Limestone assigned to *L. pulchra* was collected some 1800 km from those in the Pallinup Siltstone there can be little doubt that specimens from the two regions are conspecific, even though the Pallinup Siltstone specimens are largely preserved as internal moulds. The only differences between specimens from the two regions lies in the slightly flatter test and the more sunken periproct in the only complete uncrushed Pallinup Siltstone specimen.

Such a wide distribution for an echinoid taxon is not unusual in the living Australian fauna. For instance, *Breynia desorii* has a range of nearly 4000 km along the Western Australian coast (McNamara 1982). *Protenaster australis* has a similar range along the southern Australian coast (McNamara 1985). In addition to the occurrence of *L. pulchra* in both the Tortachilla Limestone and Pallinup Siltstone, *Gillechinus cudmorei* is also found in both units (McNamara *et al.* in press), as is *Prenaster aldingensis* A single incomplete specimen of *Giraliaster bellissae* is known from the Pallinup Siltstone. Foster & Philip (1978, p. 814) questioningly referred a specimen from the Tortachilla Limestone to this species. They also record it from the Late Eocene Wilson Bluff Formation near the South Australia/Western Australian border. They further note the similarity in age (planktic foraminiferal zones P14-15) between this unit and the Tortachilla Limestone (P15). The Pallinup Siltstone, as noted, lies somewhere within zones P15-16.

A number of species from the Australian Tertiary, as noted above, have been placed in *Linthia*. However, none belong in the genus. *Linthia antiaustralis* (Tate, 1885) has recently been placed in *Protenaster* (McNamara 1985). *Megalaster compressa* (Duncan, 1877) was placed in *Linthia* by Clark (1946), but is now regarded as belonging in *Pericosmus* (McNamara & Philip 1984).

Pericosmus nelsoni (McCoy, 1882) placed in *Linthia* by Pritchard (1908), has recently been made type species of a new genus, *Waurnia* (McNamara & Philip 1984). *Pericosmus gigas* (McCoy, 1882) was also regarded as belonging in *Linthia* by Pritchard (1908). It is now considered, along with *Linthia mooraboolensis* (Pritchard, 1908) to belong in *Victoriaster.* Consequently, the Late Eocene form described herein and placed in *Linthia,* is the only unequivocal record of the genus from the Australian Tertiary.

The only Australian spatangoid which could possibly be confused with *L. pulchra* is *Protenaster philipi* McNamara, 1985 from the Late Oligocene Waurn Ponds Limestone in Victoria. *L. pulchra* can be distinguished by its lower test, more centrally located apical system, deeper ambulacrum III, broader petals and semicircular peristome. *Protenaster preaustralis* McNamara, 1985 which coexists with *L. pulchra* in the Tortachilla Limestone, is also superficially similar, but differs in its possession of a more anteriorly situated apical system; barely sunken ambulacrum III; much shallower anterior notch; longer, narrower petals, the anterior pair running almost transversely across the test.

Linthia pulchra differs from the type species *L. insignis* (Desor, 1853; see de Loriol 1876, Pl.6, Fig. 1; Pl.7; Figs 1-2) from the Eocene of Switzerland in its broader anterior petals; more anteriorly situated apical system; lower test with truncate posterior margin; and less anteriorly projecting labrum. The Middle Eocene *L. wilmingtonensis* (W. B. Clark, 1915; see Cooke 1959, Pl.29, Figs 1-4; Kier 1980, Pl.17, Figs 3-6) from North and South Carolina has, like *L. pulchra,* a deep ambulacrum III bearing many pore pairs. The two species can be distinguished by the narrower petals of *L. pulchra* and narrower ambulacrum III.

Linthia sindensis (Duncan & Sladen, 1882-6; see Lambert 1933, Pl.4, Fig. 16) from the Eocene of Pakistan and Madagascar compares with *L. pulchra.* However, the Australian species can be distinguished by its narrower petals and deeper ambulacrum III.

Jeannet & Martin (1937) illustrated a specimen from the Late Miocene of Java which they called *Schizaster* spec. aff. *subrhomboidalis* Herklots (Jeannet & Martin 1937, Fig. 61). This rather worn specimen differs from *S. subrhomboidalis* (see Gerth 1922, Pl.62, Fig. 3) in possessing a deeper anterior notch; more anteriorly eccentric apical system; and longer posterior petals. In these respects this specimen bears some resemblance to *L. pulchra.* However, its slightly shorter posterior petals and broader ambulacrum III preclude placing the two forms in the same species.

Acknowledgments

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SPATIAL DISTRIBUTIONS OF STOCKING INTENSITY PRODUCED BY SHEEPFLOCKS GRAZING AUSTRALIAN CHENOPOD SHRUBLANDS

BY ROBERT T. LANGE

Summary

The distribution of estimated sheep stocking intensity (ha sheep^{-1}) is described from within each of several paddocks (large wire-fenced subdivisions) of arid zone stations (ranches) in Australia. The estimation method is based on demonstrated proportionality between time spent and egesta deposited by sheep in the localities they visit. Egesta deposition measurements of which the intensity estimates are transformations are shown experimentally to correlate with immediate sheep effects upon the vegetation.

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LANGE, R. T. (1985) Spatial distributions of stocking intensity produced by sheepflocks grazing Australian chenopod shrublands. *Trans. R. Soc. S. Aust.* **109**(4), 167-174, 29 November, 1985.

The distribution of estimated sheep stocking intensity (ha sheep^{-1}) is described from within each of several paddocks (large wire-fenced subdivisions) of arid zone stations (ranches) in Australia. The estimation method is based on demonstrated proportionality between time spent and egesta deposited by sheep in the localities they visit. Egesta deposition measurements of which the intensity estimates are transformations are shown experimentally to correlate with immediate sheep effects upon the vegetation.

The magnitudes of estimated sheep stocking intensity are shown to vary greatly from place to place within the one paddock. In the studied region about one third of each paddock's area experienced intensities higher than the paddock average, grading upwards to about six times higher, while about two thirds experienced lower intensities grading down to zero. Implications for perennial vegetation in the paddocks are discussed.

KEY WORDS: Chenopod shrubland, sheep grazing, stocking pressure variation.

Introduction

Sheep pastoralism in the Australian arid zone is notable for its great wool production but also for the damage which the sheep do to the perennial vegetation. There is a general belief that there are safe stocking intensities which do not harm the vegetation and excessive intensities ("overstocking") which do. Many authors have used small-paddock experimental trials (of area one ha or so) to demonstrate the relevant relationships between stocking intensity and vegetation reactions (Cunningham & Walker 1973; Hamilton & Bath 1970; Harrington 1979; Leigh & Mulham 1966; Leigh & Wilson 1969; Leigh, Wilson & Mulham 1968, 1969; Trumble & Woodroffe 1954; Tupper 1978; Williams 1970; Wilson 1974, 1976; Wilson & Graetz 1980; Wilson, Leigh & Mulham 1969; Wilson, Mulham & Leigh 1976).

The application of their results to full scale pastoral paddocks is complicated because flocks do not spend their time evenly throughout the large areas in which they wander (Waite 1896; Osborn, Wood & Paltridge 1932; Valentine 1947; McBride, Arnold, Alexander & Lynch 1967; Barker 1979; Squires 1970, 1974; Whalley, Robinson & Taylor 1978). So although the paddock average stocking intensity may be known (PSI = enclosure area divided by flocksize), the intensity on any actual part (SIP = average stocking intensity of the part) remains unknown. Without some means of estimating SIP at given points within paddocks, there is no connection with the experimental-trial literature. The difficulties of this situation were

pointed out by Rawes & Welch (1966, 1969), Ares & Leon (1972) and Anderson & Currier (1973)

An approximate solution to these difficulties follows demonstrations by Rawes & Welch (1966, 1969), Lange (1969), Ares & Leon (1972), Squires (1974), Lange & Willcocks (1978) and others, that quantitative relationships exist between flock use of pasture localities and the amounts of egesta which fall in them. From these relationships SIP can be estimated. A particular basis demonstrated by Lange (1983) is used here to examine the spatial and temporal distribution of estimated SIP in arid zone paddocks of the Whyalla region, South Australia, during the period 1969-1982.

Methods

Computations and Graphical Summaries

As in the study of Hilder (1964) the enclosure (paddock) is imagined to be divided into many equal parts from each of which egesta accumulations can be measured. Over any observational timespan the exact average stocking intensity on each part (Lange 1983) then is:

$$\frac{\text{area of the part (ha)}}{\text{enclosure} \times \text{fraction of total flocktime spent}} = \text{SIP (ha sheep}^{-1})$$
$$\text{flocksize} \quad \text{in the part } (=F)$$

The use of ha sheep^{-1} rather than its reciprocal follows Harrington (1979), Cunningham & Walker (1973), Rattray (1960), Goodall (1971) and Vesey-Fitzgerald (1974) because in the arid zone it mostly has values >1. Except in small-scale calibration experiments (Lange & Willcocks 1978; Lange 1983) there was no practicable means of obtaining F

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directly because canopies of the western myall trees (*Acacia papyrocarpa* Benth) prevented surveillance even from a tower. Egesta accumulations in contrast were easily measured and had the special advantage of reflecting total flock activity at all times in all places.

An approximate SIP was obtained for each part by substituting the fraction of enclosure total egesta deposition on the part as a surrogate for F (the fraction of total flocktime spent in the part). In this study that substitution rested on 3 experimental demonstrations in the Whyalla region, that sheeptime spent on a part was roughly proportional to egesta recovered from it ($r^2 = 0.92$ to 0.98, $p < 0.001$). This proportionality was subject to the requirement that the size of the part, the length of the accumulation span and the size of the egesta sample were all relatively large (Lange 1983).

As in similar studies (Rawes & Welch 1966, 1969; Ares & Leon 1972; Squires 1974; Hilder 1964), egesta on the part was sampled, in this case from 240 m^2 of ground surface per part. Over protracted periods it was recovered, oven dried, weighed, volumed and stored every few weeks to avoid field decay losses.
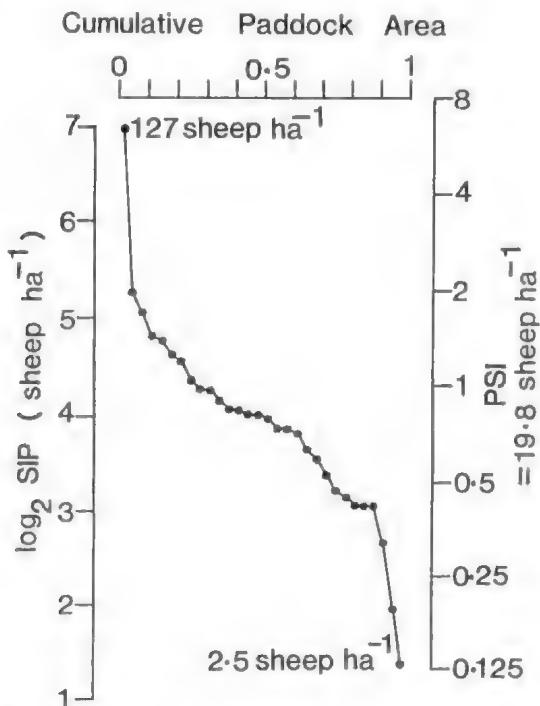
Fig. 1. The cumulative distribution of log$_2$ SIP (stocking intensity of the part) for the 30 parts of the sheep-stocked enclosure described by Hilder (1964). The right-hand scale expresses SIP variation in terms of PSI (paddock average stocking intensity). In this case sheep ha^{-1} rather than its reciprocal is used because of the very high stocking intensity.

The first form of graphical summary was the paddock cumulative distribution of log$_2$ SIP as shown in Fig. 1 which was prepared as an example from published data of Hilder (1964, his Fig. 1). This summary is directly comparable in preparation and applications to the cumulative probability distribution P_x of a normal distribution (Smith 1954, his p. 581) which in most cases it approximates. Log x is used to compress and normalize SIP scores which vary greatly even from very small heavily stocked enclosures (Hilder set 20 sheep in just over 1 ha). Log$_2$ is used because published data about the sensitivity of vegetation to SIP are from factorial experiments involving an SIP doubling scale (e.g. Wilson, Leigh & Mulham 1969; Graetz & Wilson 1979).

The second form of graphical summary was a 3-dimensional graph of which the base plane represented the paddock surface and the vertical axis was scaled in log$_2$ SIP. The surface then was contoured in intervals of one log$_2$ cycle with PSI as datum, thus exhibiting successive doublings (upwards) and halvings (downwards) of SIP from PSI. Rotation of these graphs allows perspectives of the spatial distribution of SIP as in Fig. 2 which was prepared as an example from the same data of Hilder (1964) as was Fig. 1.
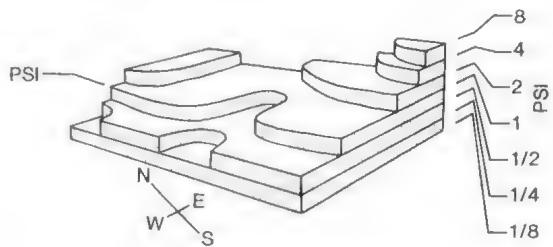
Fig. 2. Perspective view of a 3-dimensional graph showing the distribution of SIP values in the enclosure described by Hilder (1964). Values are grouped in class intervals of one log$_2$ SIP cycle with PSI as datum. The scale expresses the SIP variation in terms of PSI.

Study Locality

The studies were conducted on Middleback and Nonowie stations near Whyalla, South Australia, an environmental context which already has been thoroughly described by Barker (1979), Jessup & Wright (1971), Rogers & Lange (1971) and Noble (1979) with maps and descriptions of most of the paddocks mentioned here. It is arid chenopod shrubland of *Atriplex* and *Maireana* with variable low woodland of *Acacia*, on undulating desert loams. Rainfall is very unpredictable and averages about 220 mm yr^{-1} (1940-1970). The whole region is fenced into paddocks approximately 1200-2000 ha which are stocked continuously with merino

TABLE 1. *List of studies undertaken in the Whyalla region, South Australia, to determine the magnitudes and distributions of SIP (stocking intensity of the part of the paddock in ha sheep $^{-1}$) in each case. PSI = paddock average stocking intensity.*

Study No.	Paddock name	Area (ha)	PSI (ha sheep $^{-1}$)	Dates	Number of parts
1.	Wanga	1153	5.8	Aug. 1969-Feb. 1970 inc.	40
2.	Wertigo	2280	6.5	Oct. 1971-May 1972 inc.	37
3.	Wertigo	2280	6.5	June 1972-Sept. 1973 inc.	37
4.	Overland	1290	5.5	June 1978-Jan. 1979 inc.	50
5.	Two-Mile	1936	6.7	Sept. 1980-Nov. 1980 inc.	52
6.	Two-Mile	1936	6.7	Jan. 1981-March 1981 inc.	52
7.	Purpunda	1145	5.9	June 1982-Sept. 1982 inc.	59

sheep at PSI of about 6 ha sheep^{-1} (Lange, Nicolson & Nicolson 1984).

Validation Experiments

Validation that egesta accumulation was roughly proportional to flocktime spent by sheep in parts of the discussed paddocks was published by Lange & Willcocks (1978) and Lange (1983).

In the work of Ares & Leon (1972), validation of egesta accumulation as a useful variable to measure in pastoral research rested on the persuasiveness of its correlations with stock effects upon pasture plants. The same applied where distance from water was used as the stocking variable (Osborn, Wood & Paltridge 1932; Valentine 1947; Lange 1969; Barker & Lange 1969; Squires 1974; Graetz & Ludwig 1978; Barker 1979; Fatchen & Lange 1979). To provide an equivalent sort of validation that egesta accumulations (and hence SIP estimates) correlate with concomitant effects on vegetation in the Whyalla region, several experiments can be cited.

Lange (1984) showed that the observed probability of random outer shoots of saltbush (*Atriplex vesicaria* Heward ex Benth.) being grazed by sheep was largely accounted for by using concomitant sheep egesta accumulation as the independent variable in regression equations. Data were from bushes at arbitrary localities within 5000 ha of Whyalla shrubland ranged by sheep. The regression equation was

$$y = 11.80 + 0.17x, \ r^2 = 0.78, \ p < 0.01$$

where y was percent loss of marked shoots over a 6 week period and x was concomitant sheep egesta accumulation in kg dry wt, on plots 60 × 40 m. Across the different parts of small experimental paddocks stocked heavily, the relationship on plots 10 × 10 m was much clearer, namely

$$y = 0.416 + 0.004x, \ r^2 = 0.91, \ p < 0.001.$$

One further validation experiment[*] is reported here to extend demonstrations of the usefulness of egesta accumulation as an index of SIP, at least in some contexts. *Stipa nitida* Summerh. & C.E. Hubbard and *Danthonia caespitosa* Gaud. in Freyc. are prominent tuft grasses occurring between bushes in mixed chenopod shrubland of 2-Mile paddock (map and description in Barker 1979). A tract of this vegetation 30 × 200 m was fenced to include a drinking trough and was surveyed into 10 equal parts.

In each part all grass tufts >5 cm tall on a plot 20 × 0.2 m were estimated for biomass (g. dry wt., technique of Andrew, Noble & Lange 1979) and measured for height (cm). The enclosure was then stocked with 10 merino sheep for 6 days, the grasses then remeasured and egesta dropped by the sheep was collected from plots 28 × 2 m superimposed over the grass plots. The prediction was that egesta

[*] This experiment was performed by Chester J. Merrick, an Honours student in the author's programme.

accumulations would index reductions in grass height and biomass via regression equations.

Fullscale Studies of Paddock SIP

Table 1 lists studies which were undertaken between 1969 and 1982 (see Barker 1979, Noble 1979 and Lange, Nicolson & Nicolson 1984 for paddock maps). Wanga paddock lies east of Wertigo and Overland lies north of 1-Mile.

Results

Validation Experiment

The experiment yielded the very highly significant multiple regressions:

$$y = 36.99 - 0.47x + 0.93z, \ r^2 = 0.99,$$
$$p < 0.001$$

where y = final mean grass height (cm),
x = egesta dry wt (kg)
and z = initial mean grass height (cm)
and $y = 14.31 - 0.15x + 0.95z, \ r^2 = 0.99,$
$p < 0.001$

where y = final grass biomass (g),
x = egesta dry wt (Kg)
and z = initial grass biomass (g).

Full Scale Studies

Data from the seven separate paddocks were all the same in principle, differing only in detail of spatial pattern and particular history. A selection of data is presented here as a basis for discussion. None of the omitted cases tells a different story or contradicts the examples presented.
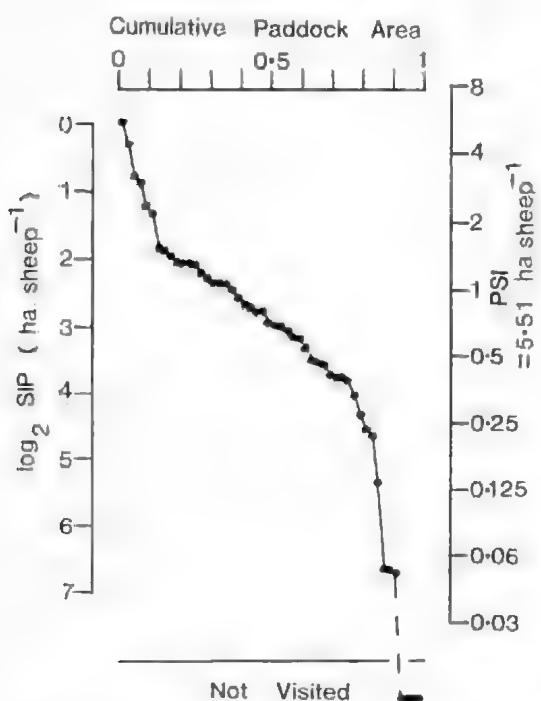
Overland Paddock (Study 4)

Fig. 3 shows the cumulative distribution of log, SIP for the 50 equal parts of Overland Paddock for the period June 1978–January 1979 inclusive. Four parts accumulated no egesta during this period so SIP for them was ∞ ha sheep^{-1}. Over the used parts of the paddock SIP values graded smoothly upwards from PSI, over about one third of the area, to a highest intensity about 2.5 cycles (6×) above PSI. Over about two thirds of the used area they graded smoothly downwards from PSI to lowest measurable intensities about 4 cycles (16×) below PSI. Only 1 of the 50 parts actually had SIP = PSI.
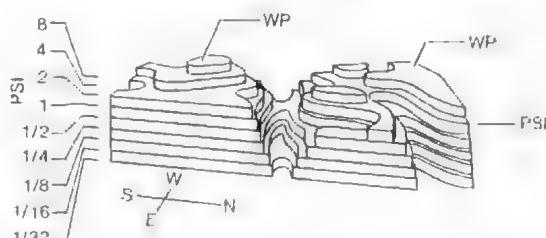
Fig. 4. Perspective view of a 3-dimensional graph showing the distribution of SIP values in Overland Paddock (Study 4). Swamp Dam is the southern water point

Fig. 4 shows the corresponding SIP surface of the paddock with log, PSI as datum and with class-intervals of 1 log, cycle. This spatial pattern had the following weather and flock management history. In June 1978 drought had restricted drinking sources for sheep in Overland paddock to Swamp Dam in the south part. The flock was observed to depend on Swamp Dam until it dried out. Then a temporary source of water was introduced (by pipeline) to a point at the west end of the north boundary of the paddock, to which the sheep were introduced.

Two-Mile Paddock (Studies 5 and 6)

Fig. 5 shows the cumulative distributions of log, SIP for spring and for summer 1980–81, respectively, in 2-Mile paddock. Fig. 6 shows these distributions compared with a theoretical normal cumulative probability distribution for the 52 parts of the paddock. The diagonals represent required lines for perfect fit and the dotted lines show observed fit.

Rank order correlation of spring and summer SIP scores across the 52 parts of 2-Mile paddock was not significant, implying that the flock shifted

Fig. 3. The cumulative distribution of log, SIP for the 50 parts of Overland Paddock June 1978–January 1979 inclusive (Study 4).
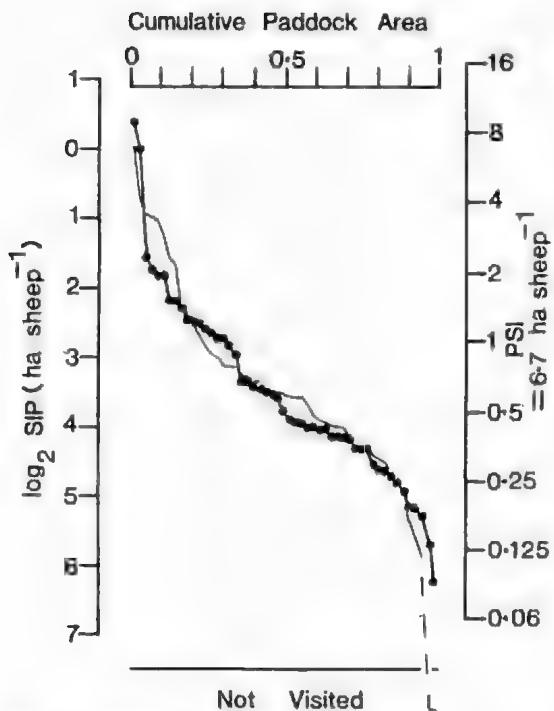
Fig. 5. The cumulative distribution of $\log_2$ SIP for the 52 parts of 2-Mile Paddock in spring (fine line) and summer (heavy line) 1980-81.

its pattern of paddock use from spring to summer, 1980-81. Hence the resemblance of spring and summer cumulative distributions is demonstrated to be independent of spatial shifting of use pattern.

Fig. 7 shows the SIP surface of 2-Mile paddock for the combined spring and summer periods. Peak stocking pressure was located not at the watering points but against the northern fence in a drainage line.

Wertigo Paddock (Studies 2 and 3).

Fig. 8 shows the SIP surface of Wertigo paddock for the period October 1971-May 1972 inclusive with $\log_2$ PSI as datum and SIP in class-intervals of 1 $\log_2$ cycle. The flock was observed throughout this period to use only the southwestern water point and to graze away from it in two directions, namely southeastwards into the southeast corner of the paddock and north along the western boundary. One part of the paddock was never visited.

Fig. 9 shows the corresponding surface for the period June 1972-September 1973. The flock was observed throughout this period to use Wertigo paddock in approximately the same pattern as previously. There was a highly significant rank correlation of SIP scores between the two periods ($r = 0.846$, $p < 0.001$), indicating relative stability
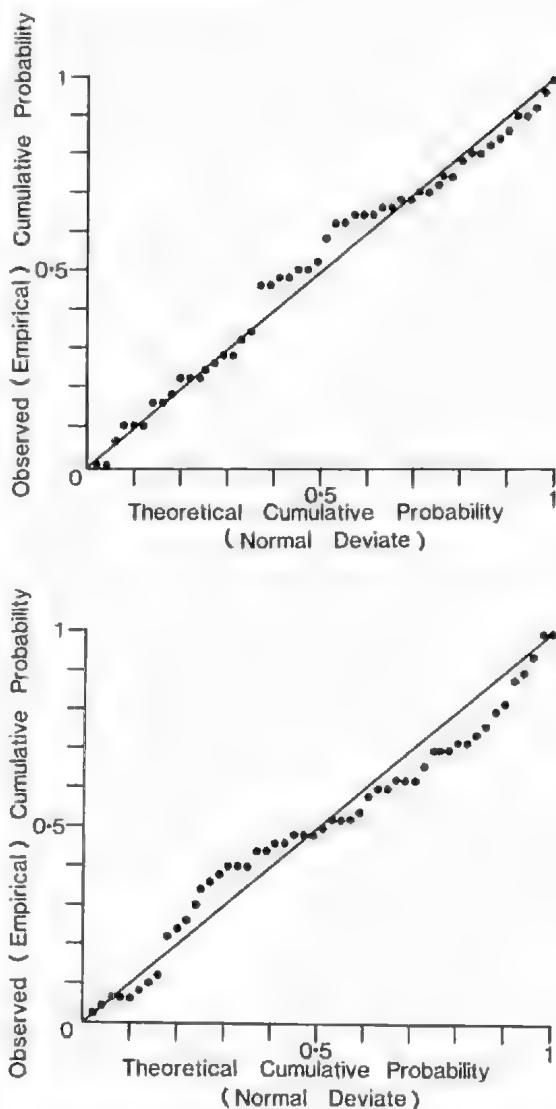
Fig. 6. The cumulative distributions of $\log_2$ SIP for spring and summer 1980-81 in 2-Mile Paddock compared with theoretical normal cumulative probability distributions. The diagonals represent required lines for perfect fit and the dotted lines show observed fit. Spring above, summer below.
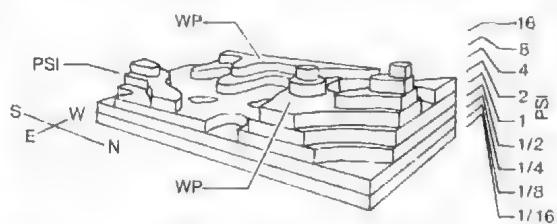
Fig. 7. Perspective view of a 3-dimensional graph showing the distribution of SIP values in 2-Mile Paddock for the combined period Spring and Summer 1980-81 (Studies 5 and 6).
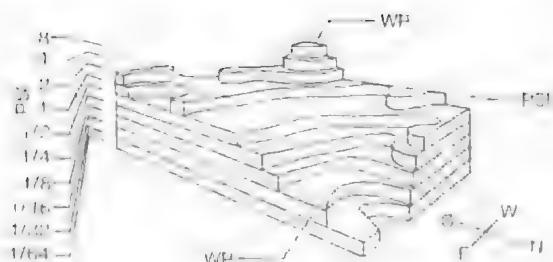
Fig. 8. Perspective view of a 3-dimensional graph showing the distribution of SIP values in Wertigo Paddock for the period Oct. 1971-May 1972 inc. (Study 2).
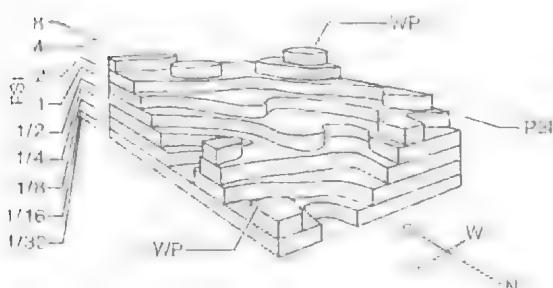
Fig. 9. Perspective view of a 3-dimensional graph showing the distribution of SIP values in Wertigo Paddock for the period June 1972-Sept. 1973 inc. (Study 3).

of use pattern. Kangaroo egesta recovered from the same places also correlated between periods (r 0.39, $p < 0.05$).

Discussion

The demonstrations by Rawes & Welch (1966, 1969) and by Ares & Leun (1972) that measurements of egesta deposition in open paddock situations index stocking intensities of sheep, are extended by the present data. That extension is not merely to the Australian arid zone context, but also towards a more quantitative footing.

Data reported here show very significant quantitative relationships between sheep egesta depositions and simultaneous effects on plants at localities throughout the range of the freely-roaming sheep flock. Furthermore those relationships have been demonstrated over time intervals so brief as to admit no scope for interpretations other than of egesta deposition as an index of simultaneous stocking or grazing pressure. The only logical conclusion from the regression equations of the validation experiment is that egesta accumulation on plots indexed the simultaneous loss of grass height and biomass caused by the sheep, and from the equation in Lange (1984) that it indexed the simultaneous eating of saltbush shoots by the flock.

To the extent that the SIP estimates reported here are direct transformations of the egesta deposition data, the SIP estimates also relate to effects of stock on vegetation. It is reasonable from the present evidence to suppose, if plants are being affected by stock in their paddock, that the plants are likely to be affected most where SIP estimates are highest and least where they are lowest. But the particular advance introduced here is the capacity to place quantitative estimates (ha sheep[1]) upon the SIP at particular places within the ranges of flocks, and thus to link those places with the extensive small-plot experimental literature mentioned in the Introduction. The results of examining those links will be discussed elsewhere; the aim here is to discuss intrapaddock SIP for its own sake.

Much evidence indicates fundamental similarities in the relationships of SIP in all paddocks examined from the Whyalla region and extending, so far as data exist, to published cases from elsewhere in Australia. Thus the logarithms of SIP values in each of the examined paddocks were approximately normally distributed. Something intrinsic in the behaviour of sheep flocks is suggested by that fact, constraining them to distribute their flocktime very unevenly, on average, throughout their range. Lest that be attributed simply to the vast range area available to relatively small flocks in the Whyalla region, or to the piosphere effect (Barker 1979), it should be recalled that the same applied even to Hilder's data concerning 20 sheep penned inside 1 ha.

That inflexibility has important practical implications. The first is that the more even spread of flocktime throughout each paddock, desired by station managers (Lange, Nicolson & Nicolson 1984), seems less likely to be achieved simply by further fencing of paddocks into smaller areas, than was earlier thought.

The second is in relation to absolute flocksize and paddock size, and PSI. It is traditional in the Australian sheep industry to make stocking comparisons just on the basis of PSI (in ha sheep[1] or, in wetter more productive places, sheep ha[1]). But as shown in Fig. 5 of Lange, Nicolson & Nicolson (1984), any particular PSI (say, 6 ha sheep[1]) is set throughout the industry by widely different combinations of flocksize and paddock size. Present results show that even in the relatively small paddocks of the Whyalla region, SIP values reflect the limits to which flocks can or will range away from their water-point. There is no evidence to suggest that those limits are different in big paddocks.

It ought to be evident from this, and from the inexorable tendency of the flock to exert SIP values greater than PSI over about one third of the flock's realized range, that PSI becomes progressively more grossly misleading as an index of SIP, as paddocks

and flocksizes increase at the one PSI. That is unless the larger paddocks have correspondingly more waterpoints, which in many Australian cases they do not.

There are other applications of the present approach which are independent of considerations of wool production and pasture. Over 60 species of rare and threatened Australian endemic flora are to be found scattered within the sheep paddocks that enmesh their remnant distributions in this region. Clearly their fate is closely related to the SIP

they experience, whether high or low. It is important to establish what their situation is, by means of the present technique, as part of developing conservation measures for them.

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THE FOSSIL SEA URCHIN FELLASTER INCISA – AN EXTENSION OF RANGE

BY T. SADLER AND N. S. PLEDGE

Summary

The fossil clypeasteroid sea urchin, Arachnoides incisa, was originally described by Tate from three specimens collected from so-called Miocene beds at Red Bluff, Lake Tyers, east Gippsland. This unit is now recognised as the Lower Pliocene Jemmys Point Formation. Foster & Philip revised the generic allocation and indicated that the species also occurs in the Pleistocene of the Parish of Werrikoo, Victoria.

THE FOSSIL SEA URCHIN *FELLASTER INCISA*—AN EXTENSION OF RANGE

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Recently, one of us (T.S.) discovered specimens at Willowbank, near Murray Bridge in the Murray Basin of South Australia, some 850 km from the type locality in the Gippsland Basin of Victoria. Subsequent investigation and collecting has produced numerous specimens. This note records the new occurrence and offers additional information on the species.

Systematics

    Class Echinoidea
    Order Clypeasteroidea A. Agassiz
    Family Arachnoididae Duncan
    Genus *Fellaster* Durham
        Fellaster incisa (Tate 1893)

Arachnoides incisa Tate, 1893: 192, pl. 13, fig. 3;

Fellaster incisa (Tate), Foster & Philip, 1980: 156, pl. 20, fig. 4, 6–7., text fig. 1.

Amended diagnosis: Test very flat, rising slightly towards apical disc; almost circular, transverse diameter slightly greater than longitudinal diameter. Apical disc slightly anterior of centre. Ambitus sharp, incised at end of each ambulacral groove, between which it is undulose. Ambulacra inflated with median depression and abruptly declivous at the sides; declivity decreases beyond end of petals. Petals reach almost two-thirds the way to ambitus, converging slightly at their ends on each ambulacrum. Ambulacra slightly more than twice width of interambulacra. Ambulacral plates obliquely combed, forming five chevron pattern pointing away from apical disc. Ornamentation minutely granular, most apparent at ambitus. Periproct supramarginal with shallow depression between it and ambitus; no definite anal notch. Peristome centrally placed and round; Actinal area slightly concave with interambulacral bulges near peristome (Fig. 1).

Material: Seven complete specimens and several nearly complete measurable specimens have been collected (Table 1), together with numerous fragments, some of which show the plate pattern clearly.

TABLE 1. *Measurements.* N, collection number, South Australian Museum; L, longitudinal diameter (from frontal lobe); T, transverse diameter; H, height; A, distance from centre of apical disc to posterior margin; P, distance from centre of periproct to posterior margin. All measurements in millimetres.

N	L	T	H	A	P
P24857	59.9	64.5		30.3	
P24858	59.8	64.3	8.1	31.2	3.8
P24859	55.4	60.2	6.9	29.3	2.8
P24860		62.8		29.2	3.1
P24861	53.0	60.6	6.2	27.5	3.5
P24862		47.3	4.6		2.7
P24864	35.1	40.8	5.1	18.4	2.6
P24865	43.5	47.2	6.4	24.2	3.4
P24866	34.6	37.8	4.4	18.0	2.7
P24867	33.2	35.5	4.0	17.5	2.6
P24869	54.5	60.2	6.2	28.7	3.1
P24870		65.2	8.0	32.8	3.9
P24871	44.0	49.6	5.8	23.7	3.1

Occurrence: Most specimens came from outcrops interpreted as Norwest Bend Formation, at Willowbank, 8 km north of Murray Bridge, and others near Sunnyside Lookout, 3 km upstream, opposite Mypolonga. Specimens occur throughout the lower 10 metres of exposed Norwest Bend Formation at Willowbank (Fig. 2). Fragments were traced as far as Ponde, 5 km south of Mannum.


Fig. 1. *Fellaster incisa*, (a) P24857, adoral, (b) P24858, adapical.
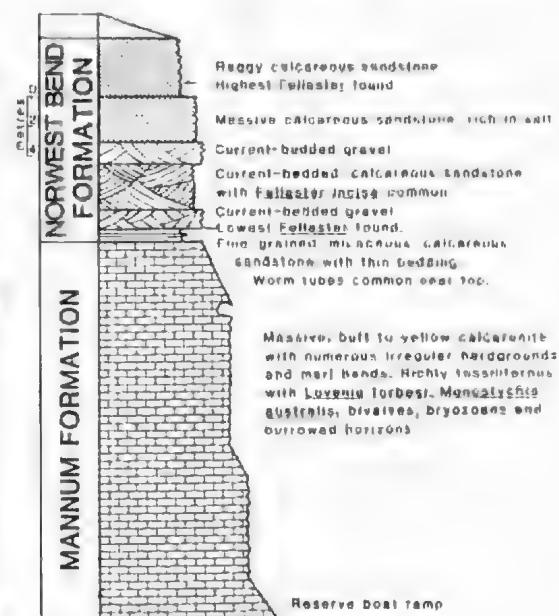
Fig. 2. Stratigraphic section at Willowbank.

Abundance and completeness of preservation decreased markedly towards this northerly location.

Remarks: In the area of interest, the Norwest Bend Formation (Fig. 2) consists of current bedded, flat-laminated and massive, medium to very coarse, micaceous sands, with some gravel bands, biogenic clasts, and well-rounded pebbles and cobbles of igneous and metamorphic rock: quartz, Kanmantoo gneisses and schists, and probable Murray Bridge Granite. Cementation varies vertically; some beds are barely cemented while others form very hard ledges. Some intervals show extensive burrowing by "worms" forming more or less vertical tubes.

Fossils are not common, and at Willowbank, specimens of *Fellaster incisa* apparently outnumber all others, which comprise mostly scallops (*Chlamys* cf. *antiaustralis*), a few fragments of *Ostrea* sp. and bryozoa. Only one other species has been found; a single specimen of a small unidentified sand dollar urchin. Some specimens of *Fellaster* show evidence of a round hole bored into the adapical surface, presumably by a carnivorous gastropod. However, no fossil gastropods were found, presumably because the porous nature of the sediment would allow their aragonite shells to be dissolved away rapidly. Molluscan fossils gradually increase in number as *Fellaster* decreases towards the northern limit of its observed range.

The largest specimens of *Fellaster* seem to occur at Willowbank while smaller ones were predominant near Sunnyside Lookout. Most specimens were found in upright horizontal position. A few, however, were overturned and one was observed in almost vertical orientation. No preferred lithology could be discerned, although better specimens seem more common in the flat laminated to massive finer sands. As would be expected, only broken fragments were found in the gravel horizons.

Conclusions: Fellaster incisa (Tate) occurred widely in southeastern Australia during the Pliocene, from the eastern Gippsland Basin to the western part of the Murray Basin. It appears to have preferred sandy bottom conditions. For reasons unknown it was one of the few animals to inhabit the Murray Bridge–Mannum area during the deposition of the Norwest Bend Formation.

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AGE AND GROWTH OF THE BLUE-THROATED WRASSE PSEUDOLABRUS TETRICUS

BY S. A. SHEPHERD AND LISA J. HOBBS

Summary

The blue-throated wrasse Pseudolabrus tetricus (Richardson) is one of the most common fishes of inshore rocky reefs on moderate to high energy coasts of southern Australia. Yet except for taxonomic and habitat notes, nothing has been published on its biology. This note describes the age dependent growth and length-weight relationships of P. tetricus.

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The blue-throated wrasse *Pseudolabrus tetricus* (Richardson) is one of the most common fishes of inshore rocky reefs on moderate to high energy coasts of southern Australia. Yet except for taxonomic and habitat notes[1,2], nothing has been published on its biology. This note describes the age dependent growth and length-weight relationships of *P. tetricus*.

This study is based on the analysis of scales of 58 individuals captured by spearing at West Island and adjacent areas in Encounter Bay, South Australia, supplemented by small samples of large individuals from Cape Jervis, Yankalilla and Gleasons Landing, Yorke Peninsula. The data for another 17 individuals were rejected because the scale circuli were too indistinct to read accurately. Three scales were taken from behind the left pectoral fin of each fish, cleaned in sodium hydroxide solution and mounted between microscope slides. Standard techniques[3] were used for reading the scales and for back-calculation of growth. Scales were examined for growth checks or closely spaced circuli by using a microfiche reader. Photocopies of the projected scale images were made and mean distances from the focus along two diagonal posterior radii (where circuli are most clearly defined) to successive circuli and to the margin were taken for each sample. The scale circuli have been found to be annular for other temperate labrids[4,5] and are therefore assumed to be annuli for this species. All lengths are expressed as total length.

The relationship between scale radius (R) in mm and total length (L) in cm was found to be linear, and the following equation was fitted to the data by the least squares method (Fig. 1).

$$R = 0.0045 + 0.405 \, L \quad (r = 0.95)$$

This equation was then used to back calculate the length of fish at the time of formation of each annulus.

Because sex inversion from female to male is size-related and occurs at a length of about 35 cm (Shepherd &

Clarkson, in prep.) data for females and males were combined for the purpose of the calculations.

The number of annuli increased with fish size, and annuli maintained the same position on the scales of fish of different ages. Subject to minor deviations discussed below mean back-calculated lengths agree with mean observed lengths at each age. Hence the back-calculations validate the technique at least for the first five age classes. Older age classes would need validation by an independent method.[6]

The means of back-calculated lengths at age were plotted by using the graphics facility of the Lotus 1-2-3 microcomputer package and a von Bertalanffy growth curve was then fitted interactively by eye. The von Bertalanffy equation for the length L_t in cm at age t in years is:

$$L_t = 46.0 \, [1-\exp(-0.22 \, (t + 0.5))]$$

Table 1 presents the mean length at capture (those in the i+ age group are aged between i and i+1 years), the back-calculated length, their means and the fitted von Bertalanffy points. The data and the fitted curve are shown in Fig. 2.
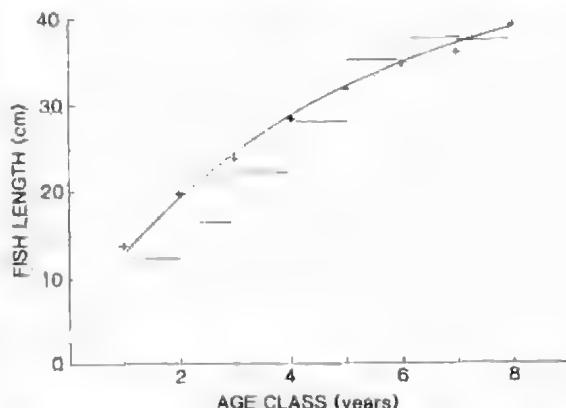

Fig. 2. Plots of true total length at age (a dash indicates the age class), lengths at age from the back-calculations (crosses), and the fitted von Bertalanffy curve for *P. tetricus*.

The length weight relationship, determined by regression analysis was $W = 0.052 \, L^{2.706}$ ($R^2 = 0.85$; $N = 61$) where W is the weight in g and L the total length in cm.

The mean back-calculated lengths up to age 4 for fish aged >4 years are greater than the true length (Table 1). This effect, if true and not an artifact of sample size, is the reverse of Lee's phenomenon[3,7,8]. Possible causes are: (1) non-random or biased sampling in which slower growing fish are under-represented; this may arise because of the gear used or the habits of the fish; and (2) selective natural or fishing mortality[3]. *P. tetricus* is not sought by commercial or recreational fishermen (although it is often a substantial part of the catch taken incidentally by recreational anglers[9]), and the sample was taken by
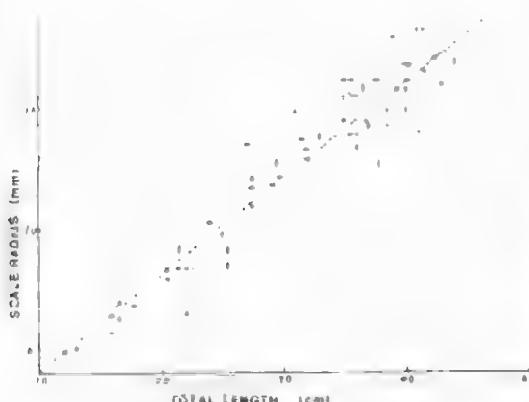
Fig. 1. Plot of scale radius versus total length for *P. tetricus*.

spearing; hence is unlikely that selective fishing mortality occurs. However, selective natural mortality in which faster growing fish survive better could occur. Alternatively biased sampling may have occurred because the largest samples were from catches of spear fishermen who selected the largest individuals for the purpose of spearfishing competitions.

Some labrids show a point of inflexion on the growth curve upon the transition from female to male[10,11]. This. growth spurt is thought to occur because energy hitherto used for egg production can be invested in growth. The plot of true length at age for *P. tetricus* (Fig. 2) shows a slight inflexion at about 5 years of age, when sex inversion occurs, but this needs verification by tagging studies.

P. tetricus appears to have a similar longevity to its warm temperate congener of northern New Zealand *P. celidotus* (Bloch & Schneider)[4].

We are grateful to J. E. Johnson and P. S. Clarkson for collecting the samples and to the latter for their preparation. Dr P. R. Sluczanowski fitted the von Bertalanffy curve and with Dr G. K. Jones criticised the manuscript.

TABLE 1. *Mean back calculated total lengths (mm) at age for* P. tetricus. *N is sample size, mean length at capture (mm) is the true length and calculated length (mm) is derived from the fitted von Bertalanffy growth curve.*

Age	N	Mean total length at capture (mm)	Von Bert. calculated total length (mm)	Annulus							
				1	2	3	4	5	6	7	8
1 +	2	125.0	129.3	102.3							
2 +	4	166.0	194.6	101.1	158.6						
3 +	10	224.3	247.0	120.8	181.3	222.0					
4 +	8	282.4	289.1	136.6	208.2	227.2	265.9				
5 +	7	354.0	322.8	167.7	214.8	254.3	293.3	327.4			
6 +	13	376.2	349.9	146.5	196.1	246.4	294.6	334.5	371.3		
7 +	6	377.7	371.7	163.5	212.6	243.7	283.0	304.7	332.6	356.1	
8 +	8	388.8	389.1	154.9	203.0	231.6	275.1	304.9	338.2	366.4	390.6
			Unweighted Mean	137	196	238	282	318	347	361	391
			Weighted Mean	142	198	237	284	321	353	362	391

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RECORDS OF ROTIFERS EPIZOIC ON CLADOCERANS FROM SOUTH AUSTRALIA

BY RUSSELL J. SHIEL AND WALTER KOSTE

Summary

In a review of the rotifer genus Brachionus (Rotifer: Monogononta), it was noted that some species typically were collected as epizoites on planktonic crustaceans. For example, Brachionus rubens and less commonly B. variabilis occurred on Daphnia and Ceriodaphnia species. Brachonius charini was reported from eastern Europe as a commensal in the branchial chamber of Coenestheria davidi, a phyllopod. B. sessilis was recorded as an epizoite of Diaphanosoma brachyurum, and the known hosts of B. rubens and B. variabilis were listed as Daphnia magna, D. pulex, D. longispina, Moina rectirostris, Ceriodaphnia sp., Polyphemus pediculus and several macroinvertebrates.

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Although *B. rubens, B. sessilis* and *B. variabilis* are known from Australian waters[4], all were collected free-swimming from the open water of billabongs (Magela Ck, N.T., and Murray-Darling River system, Vic., N.S.W.). Significantly, the host species listed by Koste[3] do not occur here[5]. We document here the first record of a facultatively epizoic brachionid from Australia, and add to both the known epizoic taxa and their "host" species.
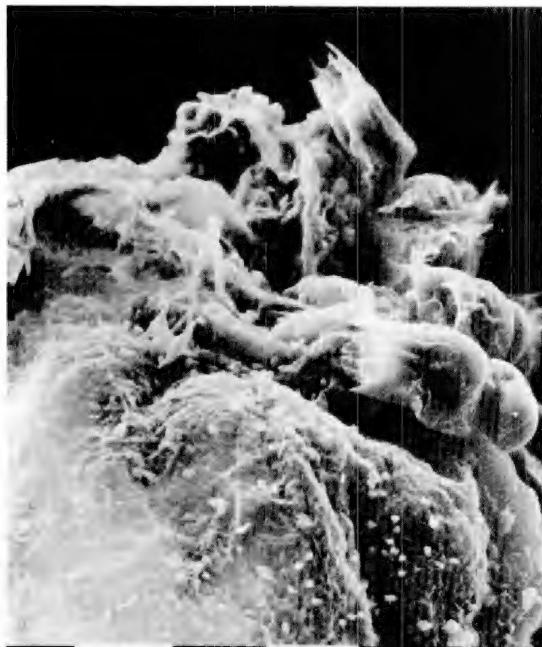
Fig. 1. LP SEM view (1.01 × 10² ×) of *B. novaezealandiae* epizoic on the head (dorsal) of *Pseudomoina lemnae. Staurastrum* (alga) and attached ciliate protozoans also can be seen.

In a collection for phytoplankton taken from a farm dam at Hahndorf, S. Aust. (27.vii.83) a rich population of planktonic cladocerans hosted a population of brachionids. The predominant cladoceran was *Pseudomoina lemnae*, with *Daphnia carinata s.l.* and *Ceriodaphnia* sp. also abundant. Most larger individuals carried from 5–40 female rotifers attached by sticky foot-gland secretions to the hosts' carapace; most of the rotifers were ovigerous, with 1–2 large amictic (parthenogenetic) eggs.

Some animals with attached rotifers were preserved in 4% formalin and prepared for light- and scanning electron microscopy (SEM)[6]. Representative SEM micrographs are shown in Figs 1 and 2. The rotifers have contracted into their loricas in response to the preservative, and some distortion of the lorica is evident, a result of the desiccation process for SEM. However, the taxonomically significant ventral margin is clear on the micrographs. The caudal lorica margin and foot-opening were examined in PVA-mounted preparations. The elongated anteromedian spines and absence of a flap over the foot-opening distinguish the specimens as *Brachionus novaezealandiae* (Morris), which, despite its name, is widely distributed in sodium-dominated waters in the southern hemisphere and may be cosmopolitan in this biotope[7].

B. novaezealandiae is not listed as epizoic by Koste[3], however Morris' original description (= *B. variabilis* var. *novaezealandiae*) notes that his material came from a pond at Totara, N.Z. "where they were in numbers, parasitic on *Daphnia thomsoni*"[8]. The type slide was found in the collection of the British Museum (Natural History), and although the coverslip was broken and the specimen somewhat desiccated and distorted through loss of mountant, it was identifiable clearly as the specimen from which Morris' figure was drawn. The slide is labelled "Proposed sp. nov. *Brachionus novae-zealandiae* C. B. Morris 1917.1.1 (all Parasitic on *Daphnia*) Totara, N. Otago. Formalin 25.10.11". Comparison of the South

Fig. 2 Anterior view (1.86 × 10² ×) of two *B. novaezealandiae*, same host. Animals are contracted. Single parthenogenetic eggs carried. Scalar 100 μm.

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Australian epizoic form and the type material indicates that the pronounced caudal spines are reduced in the S. Aust. specimens, but are within the range of variability of this species reported from R. Murray *B. novaezealandiae*[9].

Undoubtedly rotifer-cladoceran associations will be found to be more widespread among the Australian Rotifera with further study. A diverse assemblage of phytoplankton and protozoans, some of which can be seen in Figs 1 and 2, also occurred on the three cladoceran genera examined. Such epizoite communities are virtually unstudied in Australian inland waters.

We thank Brendan Atkins, then a Botany undergraduate student, University of Adelaide, for bringing this material to our attention, and Charles Hussey, British Museum (Natural History) for his hospitality and assistance during a visit by one of us (RJS) to examine the BMNH rotifer collection.

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