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First record of genus *Paradota* Ludwig & Heding in New Zealand waters and description of a new species (Echinodermata: Holothuroidea: Synaptida)

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Abstract

Davey, N. 2014. First record of genus *Paradota* Ludwig & Heding in New Zealand waters and description of a new species (Echinodermata: Holothuroidea: Synaptida). *Memoirs of Museum Victoria* 72: 1–4.

The genus *Paradota* Ludwig and Heding is recorded in New Zealand waters for the first time; nineteen specimens were found in the Bay of Plenty region of north-east New Zealand. A new species, *Paradota plentyensis* sp. nov, is described and its taxonomic position within the Order Synaptida is considered.

Keywords Echinodermata, Holothuroidea, *Paradota*, taxonomy, new species.

Introduction

A recent collection from New Zealand's eastern Bay of Plenty yielded 19 purple synaptid holothuroid specimens which lacked any body wall ossicles and did not fit into any known New Zealand genus. New Zealand currently has 12 known species in the three families Chiridotidae Östergren, 1898, Myriotrochidae Théel, 1877 and Synaptidae (Burmeister, 1837), sensu Östergren, 1898 within the order Synaptida Cuénot, 1891 (Mah et al., 2009). Most synaptid species have a worm-like appearance that can make identification quite difficult. Thus, it is likely that many more species exist in the New Zealand Exclusive Economic Zone (EEZ) which may have been misidentified in the early collection stage. Specimens in this order are relatively elusive with many species living buried in sand, mud or under various hard substrates, and are not easily seen in dive or photographic surveys. As exploration of the deep sea environment increases as part of the National Institute of Water and Atmosphere Research Ltd's (NIWA) Oceans 2020 objective to expand the knowledge of New Zealand's ocean resources, and other associated deep sea voyages are undertaken we are starting to find more new species, often with numerous representatives.

To date only three species have been described for the genus *Paradota* Ludwig and Heding, 1935 worldwide: the type species *P. ingolfi* Ludwig and Heding, 1935, from the European and American North Atlantic Coasts, *P. weddellensis* Gutt, 1990 from Antarctic waters, and *P. marionensis* Massin, 1992 from Marion Island in the southern Indian Ocean. The aim of this paper is to provide a first record of the genus *Paradota* in New Zealand waters, and to describe a fourth species in this genus. The diagnostic characters of this new species are discussed in the context of other species.

Methods

Specimens were collected by epibenthic sled and box corer from the National Institute of Water and Atmospheric Research (NIWA) research vessel RV *Tangaroa*, and after sorting were immediately preserved in 100% ethanol. Gross external morphology and basic gross internal morphology were studied under a stereomicroscope. In order to extract ossicles, the body tissue sample was dissolved in commercial bleach and initially studied with light microscopy (Nikon YS2-H). Ossicles were further examined by scanning electron microscopy (SEM) using a Hitachi TM3000 table top using the high vacuum mode at 15kV. Clean ossicles were mounted on a stud, air-dried and then coated with gold. Photos and length and width measurements of any ossicle types seen were taken using both microscope methods. All specimens were registered within the NIWA Invertebrate Collection using the prefix NIWA.

Abbreviations

NIWA	National Institute of Water and Atmospheric Research Ltd, Wellington, New Zealand. TANXXXX/xx. Voyage abbreviation and station number for *RV Tangaroa* research voyages undertaken by NIWA. Followed by year of the voyage, trip number and station number.

Systematics

Order **Synaptida** Cuénot, 1891

Diagnosis. (Smirnov, 2012) As for subclass Synaptacea Cuénot, 1891.

"Usually worm-like Holothuroidea. Tentacles peltato-digitate, digitate, pinnate, or can be secondarily simplified, simple or forked. Radial canals absent; tubefeet and anal papillae absent; canals of tentacles extending from the ambulacral ring; ampullae of tentacles are not free hanging into the body cavity. No radial hemal canals. Ring muscles not interrupted by radial muscle bands. The suborder Synaptina has organs of balance (5 pairs of statocysts) in places where radial nerves extend from the neural ring. Topographically, the primary tentacles are arranged in the way that they were initially connected with the following now missing radial canals: two with medioventral, two with the left dorsal, and one–with the right dorsal. The stone canal is attached to the body wall and opens externally or terminates in the body wall or opens into the body cavity. Respiratory trees absent. The mesentery supporting the posterior loop of the intestine is attached to the body wall in the right ventral interradius. Longitudinal muscle bands are undivided. The calcareous ring is stout. The radial and interradial segments are usually similar in shape and size. Radial segments of the ring in their upper (anterior) part have a perforation for a nerve, or sometimes it is secondarily not closed on the top and is in a shape of notch (in paedomorphic species, the segments are simple, without an anterior projection, while the radial segments do not have a perforation, or a noch for passage of the nerve). Ossicles: myritrochid or chyridotid wheels, sigmoids, anchors and anchor plates. There are no tables."

Remarks. A recent review by Smirnov (2012) into the system of class Holothuroidea resulted in changes including four new subclasses and associated orders. The order Synaptida replaces what was previously known as Apodida Brandt, 1835 and it contains the two suborders Myriotrochina Smirnov, 1998 and Synaptina Smirnov, 1998. *Paradota* belongs in the latter suborder and the Family Chiridotidae Østergren, 1898.

Suborder **Synaptina** Smirnov, 1998

Family **Chiridotidae** Østergren, 1898

Diagnosis (Smirnov, 2012). "Synaptina with 10, 12 or 18 peltato_digitate, pinnate, or secondarily simple tentacles with forked terminations. Ossicles: chiridotid wheels and/or sigmoids. Chiridotid wheels with six spokes, numerous small denticles on the inner rim and complex hub. The lower side of each spoke branches toward lower side of the egg-shaped hub to form a star-shaped structure in the centre. The tentacles and the body wall also contain rod-like ossicles with branching ends."

Genus ***Paradota*** Ludwig and Heding, 1935

Diagnosis. (Ludwig and Heding, 1935, translated by M. Reich, 10/2013; emended here). Tentacles 12, palmate in shape. Calcareous ring consists of regular flat calcareous plates with radial pieces which are usually perforated and with muscle insertion areas at the outer side. Polian vesicles numerous; ciliated funnels small and occurrence sparse. Calcareous ossicles completely missing in the body wall (except for the anterior part close to the tentacles), but present in the tentacles in the form of small rods.

Type species

P. ingolfi Ludwig and Heding, 1935: 150

Remarks. The original diagnosis for *Paradota* stated that species have 15 tentacles, yet the genus type *P. ingolfi* only has 12 tentacles. This anomaly was discussed by Gutt (1990), who noted that all *Paradota* species, including type species *P. ingolfi*, have 12 tentacles. The new species described here, *P. plentyensis* sp. nov. also has only 12 tentacles, altering this diagnostic character in Ludwig and Heding (1935). The diagnosis given here has been emended accordingly.

Paradota plentyensis sp. nov.

Zoobank LSID. http://zoobank.org/urn:lsid:zoobank.org:act:7F0984EC-E875-431F-9F58-5CF59A9BD0A2

Figure 1A–D, Table 1.

Material examined. Holotype. New Zealand, Bay of Plenty, White Island: NIWA 87163, Stn TAN1206/144, 37.53° S, 177.29° E, 1182 m, 28/04/2012. *Paratypes.* NIWA 83152 (13 specimens); same station data as holotype.

Other material. New Zealand, Bay of Plenty, Tauranga Canyon: NIWA 82999 (1 specimen) Stn TAN1206/113, 37.25° S, 176.97° E, 1222 m, 25/04/2012. Bay of Plenty, White Island: NIWA 83167 (1 specimen) Stn TAN1206/145, 37.52° S, 177.30° E, 918–1003 m, 28/04/2012, NIWA 83224 (1 specimen) Stn TAN1206/152, 37.55° S, 177.27° E, 918–1003 m, 28/04/2012. NIWA 87164 (2 specimens) Stn TAN1206/144, 37.53° S, 177.29° E, 1182 m, 28/04/2012.

Description of holotype. Paradota species 20 mm long, 4 mm wide, 4 mm high (preserved). Body form long, cylindrical with slightly bulbous posterior end (possible preservation artefact), bulbous end skin is thinner than rest of the body. Skin contracted, covered in small papillae giving a granular texture. No tube feet. Mouth is terminal, surrounded by a tentacle crown with 12 equal sized tentacles of peltato-digitate shape with 4-5 digits per side of each tentacle, which become smaller nearer the tentacle trunk.

Paratypes follow the general description above with the following differences: specimens are up to 40 mm long, 4 mm wide and 4 mm high (preserved). The bulbous end can be either anteriorly or posteriorly located.

Due to the small size of specimens the paratypes were extensively dissected. Internally the majority of the coelomic cavity is occupied by sediment filled intestine. The longitudinal muscles are large, up to 2 mm high and wide, divided. One large (1.5 mm) polian vesicle (structure responsible for maintaining water vascular system pressure) is present with 2-3 smaller thinner ones. Gonads not visible in dissected specimens but tubule like strands present posteriorly which may be undeveloped gonad material. Calcareous ring consists

Table 1. Morphological characters for all species in the *Paradota* genus.

	Location	Tentacle ossicle rod shape	Miliary granule present	Colour (preserved)	Polian vesicle number	Depth of occurrence	Number of tentacle digits (each side)	Tentacle rod length
Paradota ingolfi Ludwig and Heding, 1935	European and American North Atlantic Coast	curved	Not mentioned	Pale body with darker tentacles (no specific colour given)	>1	1750 m	7–9	200 μm
Paradota weddellensis Gutt, 1990	Antarctica	curved	No	Pale red/violet	>1	646–661 m	5–7	60 μm
Paradota marionensis Massin, 1992	Southern Indian Ocean.	'C' shaped	No	Purplish-white/ Opaque	1	237–243 m	5–7	50–100 μm
Paradota plentyensis sp. nov.	New Zealand	straight	Yes	Dark purple	>1	1182 m	4–5	70 μm

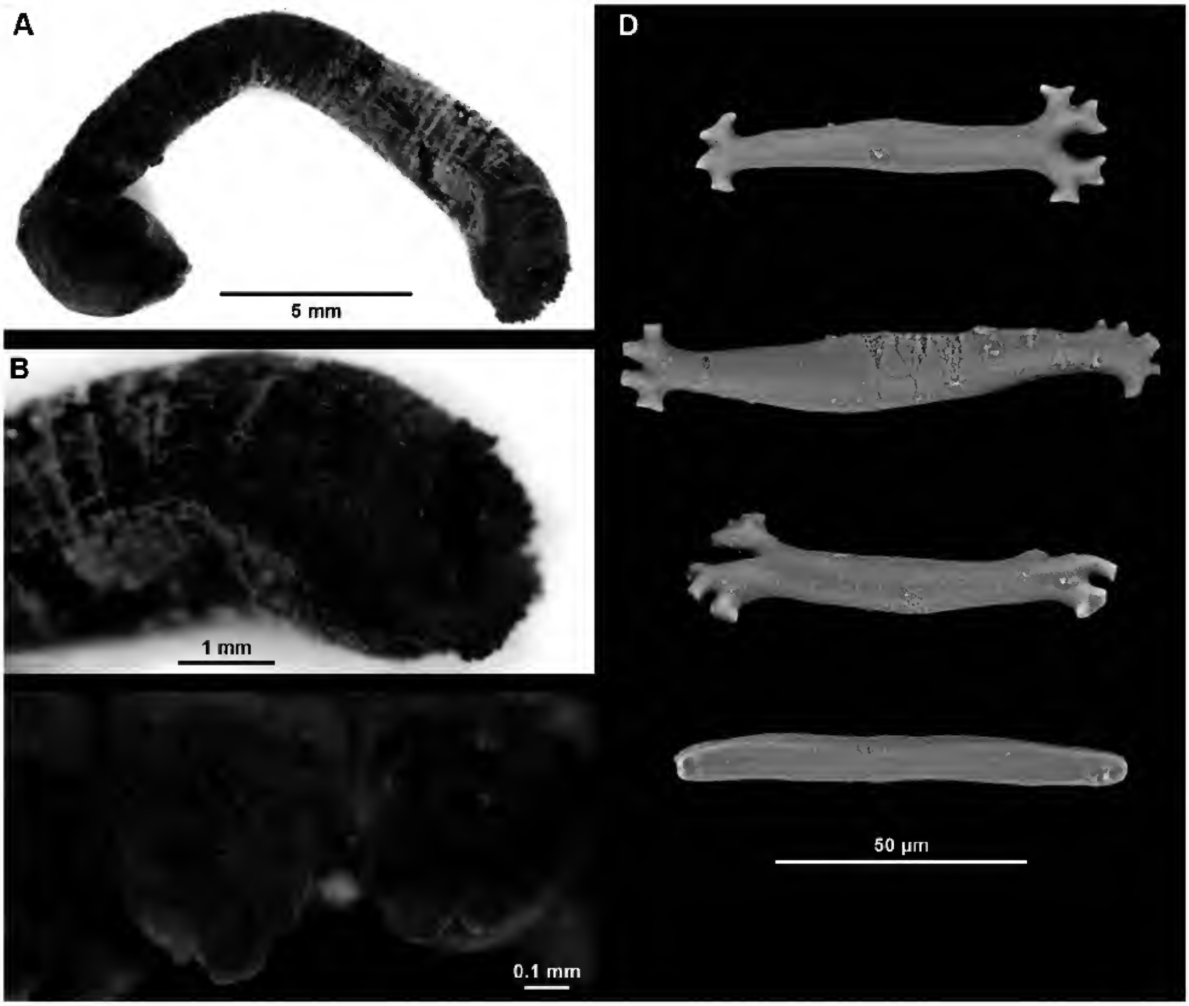

Figure 1. *Paradota plentyensis* sp. nov. holotype (A–D, NIWA 87163): A, specimen view; B, anterior view including tentacle crown; C, close up of tentacles showing 10 lobes; D, ossicle rods from tentacles.

of 12 large square pieces, radial and interradial pieces evenly sized, some radial pieces have a perforation in the upper part, posterior rim undulating.

The only ossicles present are in the tentacles and the longitudinal muscles. The body wall proper is completely devoid of ossicles. Ossicles of tentacles— smooth rods to slightly curved branched rods with varying degrees of branching distally: up to 70 μm length and 15 μm width. Ossicles of longitudinal muscles are miliary granules—smooth, oval, baton to rod-shaped: up 70 μm length and 10 μm width.

Colour. Deep purple (preserved and live)

Etymology. Named for the Bay of Plenty in the North Island of New Zealand as the type locality and presently the only known distribution for this species.

Distribution. New Zealand, Bay of Plenty, 918–1222 m.

Remarks. The lack of ossicles in the body wall and associated number of tentacles immediately indicated that we had encountered a new genus in New Zealand waters. There are three known genera within the Chiridotidae that are devoid of body wall ossicles: *Achiridota* Clark, 1908 which has 12 tentacles and is completely devoid of any ossicles; *Kolostoneura* Becher, 1909 which has 10 tentacles which do contain ossicles; *Paradota* with 12 tentacles and tentacle ossicles. Already known from New Zealand shallow waters is *Kolostoneura novae-zealandiae* Dendy and Hindle, 1907 with 10 tentacles. Our new species clearly falls into the genus *Paradota*.

Three species have been previously described for this genus. Our new species differs from them all (Table 1). Firstly the type species *P. ingolfi* from European and American North Atlantic Coast has tentacle rods which are similar in appearance to *P. plentyensis* with straight smooth lengths and branching at the extremities. However the tentacles rods are much longer (200 μm compared to 100 μm) in *P. ingolfi*.

Secondly, *P. weddellensis* Gutt, 1990 has been described from Antarctic waters. This species differs from *P. plentyensis* as it does not have miliary granules in the longitudinal muscles and the tentacle ossicles are more curved. *P. weddellensis* is a pale red to pale purple colouration compared to the deep even purple colour (live and preserved) found in *P. plentyensis*. *Paradota marionensis* Massin, 1992 was described from Marion Island in the Southern Indian Ocean. This species has similar tentacle arrangement and polian vesicles to *P. plentyensis* but is an opaque pale purple. The calcareous ring is almost identical to our new species. The tentacle ossicles are distinctly more curved in *P. marionensis* forming an almost complete ‘C’.

With a combination of the features described above we have a new species and a first encounter of the *Paradota* genus in New Zealand waters.

Acknowledgements

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New dendrochirotid sea cucumbers from northern Australia (Echinodermata: Holothuroidea: Dendrochirotida)

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Abstract

O'Loughlin, P. M., Mackenzie, M. and VandenSpiegel, D. 2014. New dendrochirotid sea cucumbers from northern Australia (Echinodermata: Holothuroidea: Dendrochirotida). *Memoirs of Museum Victoria* 72: 5–23.

A new genus in the sub-family Semperiellinae is described: *Triasemperia* O'Loughlin. Six new species of dendrochirotids are described with O'Loughlin as author: *Actinocucumis solanderi*, *Cladolabes arafurus*, *Globosita elnazae*, *Massinium bonapartum*, *Massinium keesingi*, *Triasemperia stola*. Genera *Actinocucumis* Ludwig, *Cladolabes* Brandt, *Globosita* Cherbonnier and *Massinium* Samyn and Thandar are discussed. Species listed by Heding and Panning as synonyms of *Actinocucumis typica* Ludwig are raised out of synonymy: *Actinocucumis cornus* (Heding); *Actinocucumis difficilis* Bell; *Actinocucumis longipedes* Clark; *Pseudocucumis quinquangularis* Sluiter; *Actinocucumis simplex* (Sluiter). *Actinocucumis donnani* Pearson is *incertae sedis*. We provide a table of some distinguishing morphological characters for species of *Globosita,* and a key for distinguishing the species of *Massinium.*

Keywords Northern Australia, Cladolabidae, Semperiellinae, Thyonidiidae, *Actinocucumis*, *Cladolabes*, *Globosita*, *Massinium*, *Triasemperia*, new genus, new species, synonymies

Introduction

Four recent marine surveys off northern Australia, detailed below, have collected many sea cucumber specimens. We have identified these, and specimens sent to us for identification by Geoscience Australia have been lodged with permission in Museum Victoria. A selection of specimens sent on loan by the Western Australian Museum has also been lodged with permission in Museum Victoria. Additional material from off northern Australia, held in Museum Victoria, has been studied in conjunction with these collections. The surveys referred to above are:

1. Geoscience Australia and the Australian Institute of Marine Science conducted collaborative Survey SOL4934 on the seabed environments of the eastern Joseph Bonaparte Gulf off Northern Australia in August and September 2009 on AIMS RV *Solander*. A *Post-survey Report* has been provided by Heap et al. (2010).

2. The Australian Institute of Marine Science, Geoscience Australia, the University of Western Australia and the Museum and Art Gallery of the Northern Territory conducted marine biodiversity survey SOL5650 on the Oceanic Shoals Commonwealth Marine Reserve (Timor Sea) in September and October 2012 from AIMS RV *Solander.* A *Post-survey Report* has been provided by Nichol et al. (2013).

3. The Museum and Art Gallery of the Northern Territory, in collaboration with Geoscience Australia, the Northern Territory government, and the Australian Institute of Marine Science, undertook a biological acquisition program SS2012t07 during the transit of CSIRO RV *Southern Surveyor* between Darwin and Cairns in October 2012. A *Post-survey Report* has been provided by Przeslawski et al. (2013).

4. The Commonwealth Scientific and Industrial Research Organization, in collaboration with the French *Total Foundation*, conducted a survey of the biota off the mouth of the King George River in the Kimberley region of northern Australia in June 2013 on AIMS RV *Solander.* The project leader was John Keesing, CSIRO Senior Principal Research Scientist.

In this paper one new genus and six new species of dendrochirotids are described, and additional new species await description. Tissue samples from all of the recently collected sea cucumber specimens have been sent to the University of Florida as part of a continuing project with Gustav Paulay to obtain global genetic data for sea cucumbers.

Methods

Scanning electron microscope (SEM) images were taken by Didier VandenSpiegel after clearing the ossicles of associated soft tissue in commercial bleach, air-drying, mounting on aluminium stubs, and coating with gold. Observations were made using a JEOL JSM-6480LV SEM. Measurements were made with Smile view software.

Photos of specimens were taken in Museum Victoria by Melanie Mackenzie, in collaboration with Mark O'Loughlin, using an SLR Nikon D300S digital camera with 60 mm Nikkor lens. Photos of live specimens were taken by the on-board scientists on the King George River expedition.

Abbreviations

AIMS	Australian Institute of Marine Science
CSIRO	Commonwealth Scientific and Industrial Research Organization
GA	Geoscience Australia
KGR	King George River
MAGNT	The Museum and Art Gallery of the Northern Territory
MOLAF	Prefix for code number of tissues provided to the University of Florida for sequencing
NHMUK	British Museum of Natural History
NMV	Museum Victoria, Australia, with registration number prefix F
UF	University of Florida
WAM	Western Australia Museum, with registration number prefix Z

Order **Dendrochirotida** Grube, 1840

Family **Cladolabidae** Heding and Panning, 1954 (*sensu* Smirnov 2012)

Remarks. Heding and Panning (1954) initially described the Cladolabinae as a sub-family within the Phyllophoridae Östergren, 1907. Pawson and Fell (1965) transferred the Cladolabinae to be a sub-family within the Sclerodactylidae Panning, 1949. Smirnov (2012) raised Cladolabinae to family status as Cladolabidae, based on the very short segmented or unsegmented posterior prolongations on the radial plates of the calcareous ring. The variety of ossicle form in the species of Cladolabidae suggested to Smirnov (2012) that the family might be polyphyletic.

Cladolabes Brandt, 1835

Cladolabes Brandt, 1835: 35.—Heding and Panning, 1954: 121.—Thandar, 1989: 299.—Liao and Clark, 1995: 488–489.

Urodemas Selenka 1867: 352.—H. L. Clark, 1938: 497–499.—1946: 410.

Pseudocucumis Ludwig, 1875: 90.—H. L. Clark, 1946: 405.

Diagnosis. Up to large size (150 mm long); 20 tentacles in two (15+5) or three (10+5+5) circles; tube feet scattered over the body, or confined to the radii; calcareous ring not composite, radial and inter-radial plates of ring high, posterior paired radial prolongations distinct but short, not fragmented; ossicles either tables with rudimentary disc and tall two-pillared spires or rudimentary spires, or irregular short thick variably spinous rods and clubs related to tables; rosettes frequently present.

Type species. *Cladolabes limaconotus* Brandt, 1835 (by monotypy) (NW Pacific)

Other species, with distributions. *Cladolabes aciculus* (Semper, 1867) (Fiji, tropical Indo-West Pacific); *C. arafurus* O'Loughlin, sp. nov. (below) (NE Australia); *C. bifurcatus* (Deichmann, 1944) (Natal, South Africa); *C. crassus* (H. L. Clark, 1938) (Hong Kong); *C. hamatus* (Sluiter, 1914) (Indo-Malayan Archipelago); *C. perspicillus* (Selenka, 1867) (E Australia); *C. pichoni* Cherbonnier, 1988 (Madagascar); *C. roxasi* (Domantay, 1934) (Philippines); *C. schmeltzii* (Ludwig, 1875) (NE Australia to S China).

Remarks. We have emended the earlier diagnoses of Heding and Panning (1954), Thandar (1989) and Liao and Clark (1995) to include the presence of rudimentary table spires that are present in our new species (below). We noted above that the variety of ossicle form in the species of Cladolabidae suggested to Smirnov (2012) that the family might be polyphyletic. We endorse this view for the same reason. For this same reason, and the added reason of the variation in tube foot distribution, we judge that *Cladolabes* might also be polyphyletic.

Cladolabes arafurus O'Loughlin, sp. nov.

Zoobank LSID. http://zoobank.org:act:AB27AA20-F074-4C3B-BABE-242616AD4A2F

Figures 1, 2.

Material examined. Holotype. N Australia, Arafura Sea, GA cruise SS2012t07, stn/site 01BS01, sample 110, 11.23°S 134.73°E, RV *Southern Surveyor*, benthic sled, 31 m, B. Alvarez de Glasby et al., 16 Oct 2012, NMV F202989 (UF tissue lot MOLAF1530).

Paratype. NE Australia, Queensland, Yeppoon, dredged off Middle Island, 23.13°S 150.74°E, 9–37 m, B. J. Smith, 6 Sept 1967, NMV F204070 (1).

Description. Form sub-spherical, up to 63 mm long (preserved), slightly convex dorsally, deeply convex ventrally, mouth anterior dorsal, anus posterior dorsal, slightly developed oral and anal cones (preserved); dorsal body wall thicker than ventral wall, creased, covered closely with numerous tube feet, diameters about 0.5 mm; ventral body wall thin, scattered cover of tube feet; lacking anal scales; 20 dendritic tentacles, 15 large (variable sizes) in outer circle, 5 smaller (not significantly smaller) in inner circle (proximal peri-oral); calcareous ring not composite, radial and inter-radial plates of ring high, narrow anteriorly, posterior paired radial prolongations distinct, short, not fragmented; single polian vesicle; gonad tubules branched basally; respiratory trees extending throughout coelom.

Ossicles sparsely scattered in mid-body dorsal and ventral body wall, small plates, rods and rosettes; plates frequently regular, oval with 2 large central perforations and single smaller perforation at each end (judged to be reduced table discs), short blunt pillar frequently projecting from centre of plate (judged to be reduced spires), plates 56–90 µm long; rods related to plates, 1 or 2 perforations, sometimes with central short pillar, up to 70 µm. Peri-anal body wall ossicles plates, rods, rosettes and small scales; plates similar to mid-body wall (judged to be reduced tables); rods irregular, many branched, distal ends of rod and branches widened and perforate, up to 120 µm long; multi-layered anal scale about 320 µm long. Tube feet endplate diameters up to 400 µm, tube foot and endplate support ossicles elongate perforated curved plates up to 160 µm long. Tentacles with rod ossicles and rosettes; rods fine to thick, ends widened with few perforations, rods up to 400 µm long. Oral disc and introvert with abundant rosettes, rosette rods and rare plates.

Preserved body colour off-white with fine brown flecking and spotting, tube feet brown.

Distribution. N Australia, Arafura Sea to Yeppoon, 9–37 m.

Etymology. Named for the Arafura Sea from which the type specimen was collected.

Remarks. We had considerable difficulty in finding a genus to which we should refer this new species, but we did not feel justified in establishing yet another new dendrochirotid genus. We refer the new species to *Cladolabes* with major reservations. We judge that the plates with short central pillars of *Cladolabes arafurus* O'Loughlin sp. nov. are related to table discs and spires, the latter very reduced. This would account for the unusual ossicle forms. We have emended the diagnosis of *Cladolabes* to include this character. But we recognize that the reduced tables in species currently referred to *Cladolabes* are generally characterized by a rod-like spire and reduced disc, the opposite to *Cladolabes arafurus.* The forms of the calcareous ring in species currently referred to *Cladolabes* are quite variable but generally the inter-radial plates have posterior prolongations and are not truncate posteriorly as in *Cladolabes arafurus.* We anticipate that emerging genetic data will result in a major revision of family Cladolabidae and await this evidence as to where the new species belongs generically. The form of the ossicles is distinctive, especially what we judge to be the reduced tables, and distinguishes *Cladolabes arafurus* from all other species in the genus.

Globosita Cherbonnier, 1958

Sphaerella Heding and Panning, 1954: 111 (occupied generic name).
Globosita Cherbonnier, 1958: 198 (replacement name).

Diagnosis. Cylindrical to ovoid dendrochirotid species, up to 100 mm long (preserved), sometimes with short oral and anal cones; mouth anterior dorsal, anus posterior dorsal; lacking anal teeth; 20 dendritic tentacles, 15 large, 5 inner small; radial plates of calcareous ring with paired composite posterior prolongations, each comprising up to about 6 discrete segments; inter-radial plates truncate or with notch posteriorly, lacking posterior prolongations; tube feet scattered over whole body, more numerous dorsally or ventrally; gonad tubules in 2 tufts, branched.

Body wall ossicles thick plates, irregularly round to oval to sub-rectangular, up to 90 µm long, perforations very small or lacking, sometimes finely knobbed on margin and surface, plates sometimes with 4 larger central perforations, sometimes with one large central perforation surmounted by a cross; tables with four pillars sometimes present in body wall, spires sometimes incomplete; rosettes may be present; tentacles with rods, perforated distally.

Type species. Globosita argus (Heding and Panning, 1954) (type locality Java).

Other species, with distributions. Globosita dobsoni (Bell, 1883) (Honduras); *G. elnazae* O'Loughlin sp. nov. (N Australia); *G. murrea* Cherbonnier, 1988 (Madagascar).

Remarks. Cherbonnier (1958) recognized that the genus name *Sphaerella* was occupied, and provided the replacement name *Globosita*. Cherbonnier (1988) examined the holotype of *Globosita argus* and observed 'pseudo-tables'. Deichmann (1930) expressed the opinion that the juveniles of *Globosita dobsoni* would have tables.

Table 1. Some distinguishing morphological characters of *Globosita* species.

Globosita **species** Type locality	**Largest specimen**	**Tube foot distribution**	**Rosette ossicles**	**Plate perforations**	**Plate ossicles**
G. argus Java	92 mm long sub-spherical	more dense ventrally	absent	few, minute to absent	smooth
G. dobsoni Honduras	80 mm long ovoid form	more dense ventrally	present	commonly 4 small centrally	finely knobbed
G. elnazae North Australia	100 mm long sub-spherical	more dense dorsally	absent	some numerous, some large centrally	finely knobbed
G. murrea Madagascar	40 mm long ovoid form	more dense ventrally	present	some numerous, not large centrally	knobbed on margin

Globosita elnazae O'Loughlin sp. nov.

Zoobank LSID. http://zoobank.org:act:4E654BA2-1AC4-41AE-A52D-B6891E620792

Figures 3, 4, table 1.

Material examined. Holotype. NW Australia, Joseph Bonaparte Gulf, Kimberley region, off King George River, 13.79°S 127.24°E, RV *Solander*, 55 m, J. Keesing, 10 Jun 2013, WAM Z27872 (KGR lot 23426; UF tissue lot MOLAF1484).

Paratypes. Off King George River, 13.85°S 127.29°E, RV *Solander*, 45 m, J. Keesing, 6 Jun 2013, WAM Z27861 (1) (KGR lot 23322; UF tissue lot MOLAF1459); 13.82°S 127.32°E, 73 m, 12 Jun 2013, WAM Z27853 (1) (KGR lot 29381; UF tissue lot MOLAF1442); 13.90°S 127.33°E, 11 m, 7 Jun 2013, NMV F202999 (2) (KGR lot 23425; UF tissue lots MOLAF1468, 1469).

Other material. NE Australia, Queensland, near Cairns, Machans Beach, 16.85°S 145.73°E, on beach after cyclone, B. Collins, 25 Dec 1996, NMV F203014 (1).

Description. Form sub-spherical, up to 100 mm long (preserved), slightly convex dorsally, deeply convex ventrally, mouth anterior dorsal, anus posterior dorsal, slightly developed oral and anal cones (preserved); lacking anal scales; thin soft body wall, slightly thicker dorsally; tube feet scattered over body, closer dorsally, clusters of numerous tube feet around mouth and anus, diameters about 0.4 mm; 20 dendritic tentacles, 15 large outer, 5 small inner (proximal peri-oral); calcareous ring composite, radial plates with paired tapered posterior prolongations comprising about 3 discrete segments; inter-radial plates pointed anteriorly, deep notch posteriorly, lacking posterior prolongations; single polian vesicle; madreporite multi-lobed, near posterior end of calcareous ring; gonad tubules short with numerous branches; respiratory trees extending the length of the coelom.

Ossicles scattered sparsely in dorsal and ventral body wall, regular to irregular thick oval plates and incomplete tables; larger regular dorsal plates oval to rounded sub-rectangular in form, some with large central perforation with cross and 4 truncate pillars (not amongst ossicles illustrated), large and small surrounding perforations, surface sometimes finely knobbed,

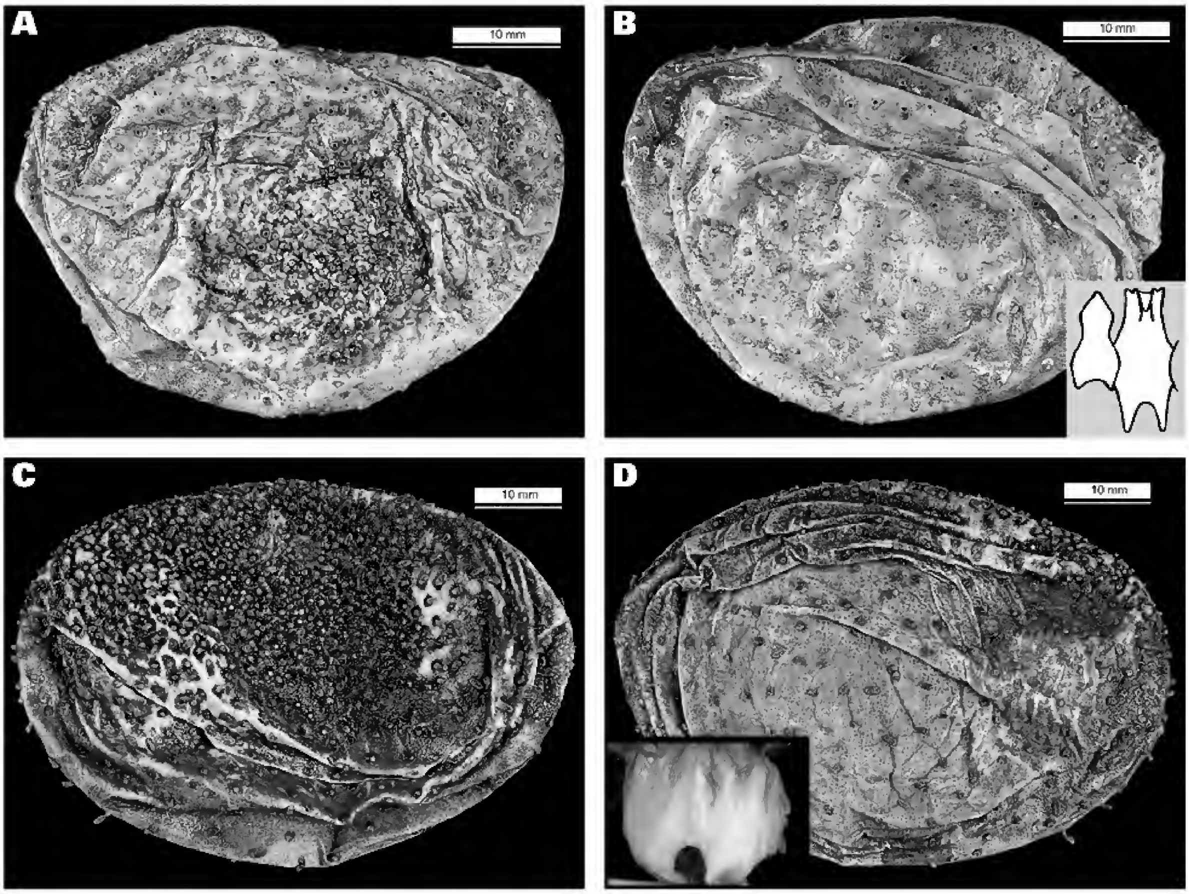

Figure 1. Photos of preserved and collapsed specimens of ***Cladolabes arafurus*** O'Loughlin sp. nov. A, dorsal view of holotype (NMV F202989, 50 mm long); B, ventral view of holotype; insert with sketch of the calcareous ring of the holotype; C, dorsal view of paratype (NMV F204070, 63 mm long); D, ventral view of paratype; insert with photo of the calcareous ring of the paratype.

margin finely spinous, plates up to 90 μm long; smaller irregular dorsal plates round to irregular in form, frequently with small perforations, sometimes with 2 large central perforations, surface variably finely knobbed, margin irregular to finely spinous, plates 40–70 μm long. Ventral body wall with some tables, oval discs up to 100 μm long, spires low, 4 pillars, sometimes not connected distally, sometimes with connecting distal bridge with short blunt spines. Tube feet endplate diameters about 250 μm, tube foot and endplate support ossicles elongate perforated curved plates up to 160 μm long. Peri-anal body wall with tables, endplates, tube foot support rod-plates; table discs irregularly round to rounded square, up to 80 μm wide, spires with 4 pillars, short spines distally; endplates about 100 μm diameter; tube foot support ossicles short, thick curved, rod-plates, about 100 μm long. Tentacles with rod ossicles only, rods smooth, ends widened with few perforations and denticulate margin, rods up to 120 μm long. Rosette ossicles not observed in tentacles or peri-anal body wall.

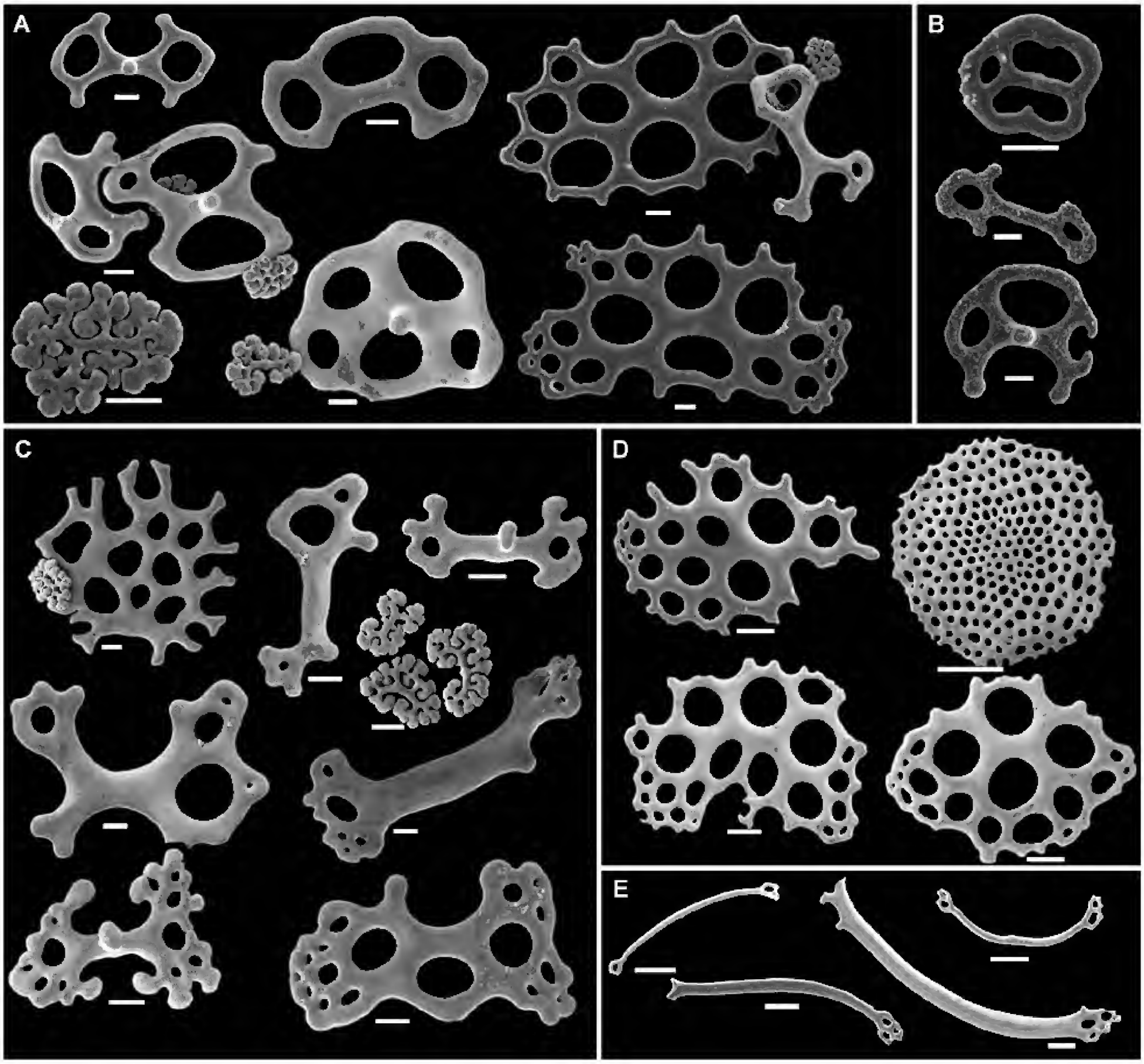

Figure 2. SEM images of ossicles from the holotype of ***Cladolabes arafurus*** O'Loughlin sp. nov. (NMV F202989). A, mid-dorsal body wall and tube feet small plates (reduced table discs), some with central short pillar (reduced spires), rosettes, and tube feet support plates (large, right) (scale bars 10 μm); B, ventral mid-body wall reduced tables (scale bars 10 μm); C, peri-anal body wall small endplate (top left), reduced tables with central short pillar, rods, and rosettes (scale bars 10 μm); D, ventral tube foot endplate (top right, scale bar 100 μm), and tube foot support plates (scale bars 20 μm); E, tentacle rods (scale bars 20 μm).

Colour live pale yellow to off-white; colour preserved off-white to pale brown, tube feet mostly with brown rim.

Distribution. N Australia, off King George River, Kimberley region, north Western Australia, to near Cairns, Queensland, 11–73 m.

Etymology. Named *elnazae* for Elnaz Tavancheh (Museum Victoria Volunteer), with appreciation of Elnaz's generous and skilled assistance with sea cucumber systematics.

Remarks. The distinguishing characters of *Globosita elnazae* O'Loughlin sp. nov. are the more abundant tube feet dorsally and the presence of a large central perforation surmounted by a cross in some plate ossicles. We note that for Cherbonnier 1988 fig. 93, illustrating the ossicle for *Globosita murrea*, fig. "E" illustrating rosettes should be "H" and fig. "H" illustrating tables should be "K". In *Globosita elnazae* we did not observe rosettes. *Globosita elnazae* sp. nov. is distinguished from the other species in the genus by the combination of morphological characters summarized in Table 1.

Family **Thyonidae** Panning, 1949 (sensu Smirnov 2012)

Sub-family **Semperiellinae** Heding and Panning, 1954

Diagnosis (emended from O'Loughlin et al. *(2012) and Smirnov (2012)).* Dendrochirotid species with 20 dendritic tentacles; calcareous ring composite, comprising a mosaic of small pieces or discrete segments; radials and inter-radials prolonged posteriorly, prolongations frequently merge to create a tubular ring; radials frequently with median division for most of the length creating 2 narrow posterior prolongations that sometimes fuse with inter-radials, distal ends sometimes cross-linked; body wall tables with 2 or 3 or 4 spires.

Remarks. Smirnov (2012) raised the sub-family Thyoninae Panning, 1949 to family status as Thyonidae, with a diagnostic emphasis on the mosaic structure of the composite and frequently tubular calcareous ring. He included the two sub-families Thyoninae (with 10 tentacles) and Semperiellinae (with 15 or 20 tentacles). O'Loughlin et al. (2012) noted that Rowe and

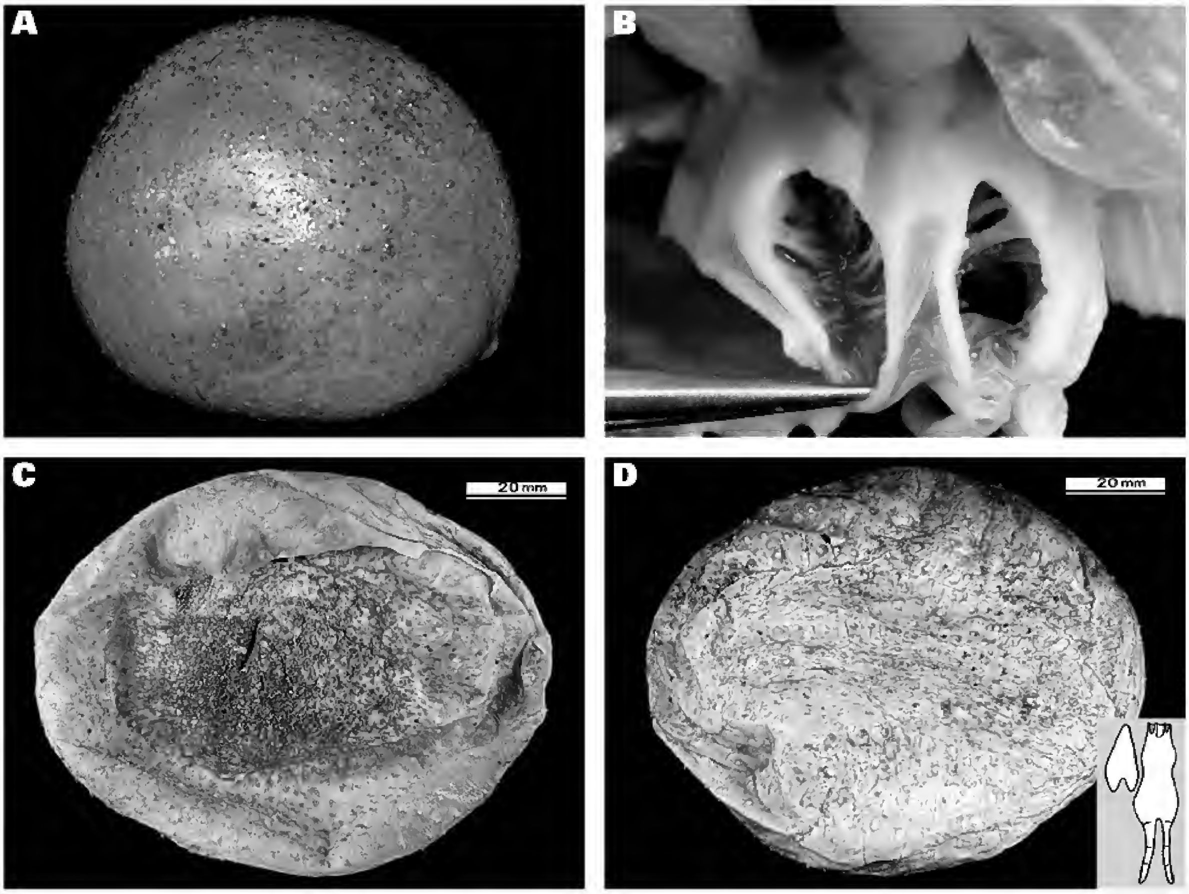

Figure 3. Photos of live, and preserved and collapsed, holotype specimen of ***Globosita elnazae*** O'Loughlin sp. nov. (WAM Z27872). A, ventro-lateral view of the live holotype specimen; B, photo of the calcareous ring of the holotype; C, dorsal view of the preserved holotype (100 mm long); D. ventral view of the preserved holotype; insert with sketch of the calcareous ring of the holotype.

Richmond (2004) judged that *Semperiella* Heding and Panning, 1954 (in the then new sub-family Semperiellinae) is a junior synonym of *Thyonidiella* Heding and Panning, 1954 (in the then new sub-family Phyllophorinae). As a consequence genera of the sub-family Semperiellinae have 20 tentacles. We have emended the diagnosis of Semperiellinae to include this fact, to include species with tables that have three pillars in each spire (see new genus and species below), and to provide a more detailed description of the calcareous ring. Michonneau and Paulay (2014) judged that *Semperiella* and *Thyonidiella* are junior synonyms of *Phyrella* Heding and Panning, 1954, and referred *Phyrella* to the Phyllophoridae Östergren, 1907. They suggested that a phylogenetic re-assessment of the family Phyllophoridae remains unresolved. We recognize that molecular genetic data will be crucial to resolving the many emerging issues.

Massinium Samyn and Thandar, 2003

Massinium Samyn and Thandar, 2003: 136.—Samyn et al., 2010: 2.

Diagnosis. Frequently semi-spherical species with oral and anal dorsal orientations; 20 dendritic tentacles arranged in two circles of 10 large outer and 10 small inner (proximal peri-oral); tube feet distributed all over mid-body; calcareous ring elongate, tubular, with both radial and inter-radial plates fragmented into a mosaic of small pieces, and posterior prolongations linked distally to form inter-radial oval non-calcified spaces beneath the water vascular ring; polian vesicles from 1 to 4; ossicles variably include granuliform rods, rosettes, pseudo-buttons and tables; table spires with 1 or 2 or 3 or reduced pillars.

Type species. *Massinium maculosum* Samyn and Thandar, 2003 (original designation) (South Africa).

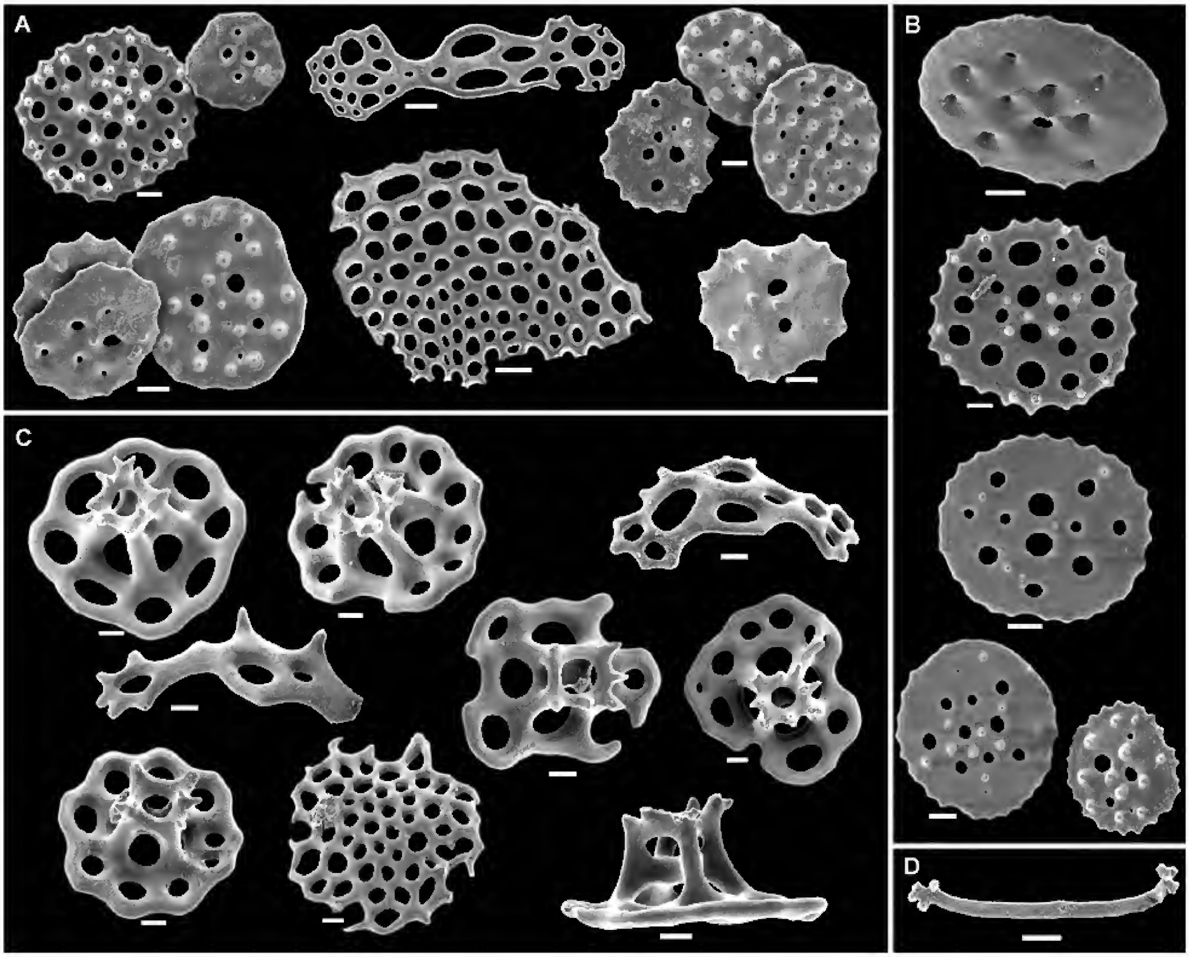

Figure 4. SEM images of ossicles from the holotype of ***Globosita elnazae*** O'Loughlin sp. nov. (WAM Z27872). A, dorsal mid-body wall and tube feet small knobbed plates, tube foot support plate (centre top), and endplate fragment (centre bottom) (scale bars 10 μm); B, ventral mid-body wall knobbed plates (scale bars 10 μm); C, peri-anal body wall tables, small endplate, and tube foot support rod-plates (scale bars 10 μm); D, tentacle rod (scale bar 10 μm).

Other species, with distributions. Massinium albicans Samyn et al., 2010 (New Caledonia); *M. arthroprocessum* (Thandar, 1989) (South Africa); *M. bonapartum* O'Loughlin sp. nov. (NW Austraila); *M. dissimilis* (Cherbonnier, 1988) (Madagascar); *M. granulosum* Samyn et al., 2010 (NE Australia); *M. keesingi* O'Loughlin sp. nov. (NW Australia); *M. magnum* (Ludwig, 1882) (Indonesia); *M. melanieae* O'Loughlin in O'Loughlin et al., 2012 (S Australia); *M. vimsi* O'Loughlin in O'Loughlin et al., 2012 (SE Australia); *M. watsonae* O'Loughlin in O'Loughlin et al., 2012 (SE Australia).

Remarks. We have emended the diagnosis of *Massinium* from that in Samyn et al. (2010) to reflect our observations in this review.

Key to the species of *Massinium*

1. Ossicles present in the mid-body wall **2**

— Mid-body wall lacking ossicles **9**

2. Mid-body wall with table ossicles of some form present **3**

— Mid-body wall lacking any form of table ossicles **6**

3. Mid-body wall ossicles tables only **4**

— Mid-body wall ossicles tables and additional ossicle forms **5**

4. Peri-oral table spires well developed, typically with long, splayed, pointed apical spines .... ***M. bonapartum*** sp. nov. (NW Australia)

— Peri-oral table spires frequently absent or reduced, few short apical spines .... ***M. keesingi*** sp. nov. (NW Australia)

5. Mid-body with rare but developed table ossicles; tentacles with table ossicles; up to 2 polian vesicles .... ***M. dissimilis*** (Madagascar)

— Mid-body with reduced table ossicles; tentacles with rosettes only; typically 4 polian vesicles .... ***M. magnum*** (Indonesia)

6. Mid-body wall with rosettes present **7**

— Mid-body wall lacking rosettes **8**

7. Introvert table discs irregular with predominantly 4 central perforations and single ring of smaller outer perforations; tentacles with rods and rosettes .... ***M. maculosum*** (South Africa)

— Introvert table discs irregular with predominantly 4 central perforations and up to 3 rings of smaller outer perforations; tentacles with elongate rod-rosettes .... ***M. albicans*** (New Caledonia)

8. Mid-body ossicles predominantly short, thick, irregular, rarely perforate, granuliform rods; tentacles with rosette ossicles only .... ***M. granulosum***. (NE Australia)

— Mid-body ossicles predominantly U-shaped, distally perforate rods; tentacles with rod ossicles only .... ***M. arthroprocessum*** (South Africa)

9. Large and small tube feet uniformly distributed; 4 polian vesicles; peri-anal body wall with table ossicles .... ***Massinium melanieae*** (Great Australian Bight)

— Tube feet not uniformly distributed; fewer than 4 polian vesicles; peri-anal body wall lacking table ossicles **10**

10. Tube feet scattered dorsally, more prominent ventrally; peri-oral table discs with up to 20 perforations; tentacles with rods and rare rosettes .... ***Massinium vimsi*** (Bass Strait, SE Australia)

— Tube feet more concentrated along longitudinal muscles; peri-oral table discs with up to 40 perforations; tentacles with rare fine rods, lacking rosettes .... ***Massinium watsonae*** (SE Tasmania, Australia)

Massinium bonapartum O'Loughlin sp. nov.

Zoobank LSID. http://zoobank.org:act:C34C417F-9A65-4346-8145-ED9E350D7E21

Figures 5, 6, key.

Material examined. Holotype. NW Australia, Joseph Bonaparte Gulf, Kimberley region, off King George River, 13.85°S 129.29°E, RV *Solander*, 45 m, J. Keesing, 6 Jun 2013, WAM Z27860 (KGR lot 23323; UF tissue lot MOLAF1457).

Paratype. Joseph Bonaparte Gulf, 11.54°S 129.83°E, RV *Solander*, 173 m, Geosciences Australia, 14 Sep 2009, NMV F202985 (1) (GA lot SOL4934 35BS24; UF tissue lot MOLAF1519).

Description. Form sub-spherical, slightly elongate, up to 43 mm long (preserved), mouth anterior dorsal, anus posterior dorsal, slightly developed oral and anal cones; firm leathery body wall; tube feet scattered over body, withdrawn, diameters about 0.2 mm, sparse dorsally, close cover ventrally and around mouth and anus; 20 dendritic tentacles, 5 pairs large in an outer ring, 5 pairs very small in an inner ring (proximal circum-oral); calcareous ring long, tubular, composite; radial plates blunt anteriorly with 2 lateral shallow notches and deeper central notch, radial plates lacking median un-calcified section; inter-radial plates pointed anteriorly, large oval un-calcified posterior section closed distally by thin calcified link; 2 polian vesicles; short branched gonad tubules; respiratory trees extending the length of the coelom.

Ossicles in mid-body wall tables only, sparse dorsally, more numerous ventrally; table disc outlines irregularly round, typically 4 larger central and some small outer perforations, margin smooth or spinous, discs up to 112 μm wide; spires with 2 frequently fused pillars, low or residual, few thick blunt apical spines. Oral disc with abundant tables with discs up to 112 μm long, irregularly oval, many perforations, margins smooth; spires discrete, up to 70 μm long, 2 partly fused pillars, rarely single, 1 to 3 median perforations, long apical spines typically widely splayed. Peri-anal body wall with abundant tables similar to those in the mid-body wall; some rods with distal perforations, rods up to 80 μm long; small multi-layered anal scales about 200 μm long. Tube feet with endplates, up to 320 μm diameters, margin thick, lacking support ossicles; body wall type tables. Tentacles with abundant rods and rosette-like rod ossicles and some tables;

rods up to 70 μm long with ends widened with few perforations; rosette-like rods up to 88 μm long with short rod widened distally with many small perforations created by dendritic branch fusing; few tables, similar to those in peri-oral disc.

Colour live off-white to pale yellow; colour preserved off-white to pale brown, tube feet brown; tentacle dendritic branches black, trunks off-white to grey.

Distribution. NW Australia, Joseph Bonaparte Gulf, Kimberley region, off King George River, 45–173 m.

Etymology. Named with reference to the *Joseph Bonaparte Gulf* from which the type specimens were collected.

Remarks. A distinctive character of *Massinium bonapartum* O'Loughlin sp. nov. is the widely splayed long apical spines frequently present on the tables. We observed the five pairs of small tentacles to be in an inner ring. *Massinium bonapartum* sp. nov. is distinguished from other species in the genus by the combination of morphological characters shown in the key.

Massinium keesingi O'Loughlin sp. nov.

Zoobank LSID. http://zoobank.org:act:BDDF31E0-C687-4932-9541-A2C40266126C

Figures 7, 8, key.

Material examined. Holotype. NW Australia, Joseph Bonaparte Gulf, Kimberley region, off King George River, 13.85°S 127.29°E, RV *Solander*, large epibenthic sled, 45 m, J. Keesing, 6 Jun 2013, NMV F203008 (KGR lot 23324; UF tissue lot MOLAF1458).

Description. Form sub-spherical, 40 mm long (preserved), mouth anterior dorsal, anus posterior dorsal, slightly developed oral and anal cones (preserved); firm leathery body wall; tube feet scattered over body, withdrawn, sparse dorsally, more numerous ventrally, diameters about 0.2 mm; 20 dendritic tentacles, 5 pairs large in an outer ring, 5 pairs very small in an inner ring (proximal circum-oral); calcareous ring long, tubular, composite; radial plates blunt anteriorly with 2 lateral small notches and deeper central notch, most of radial plates

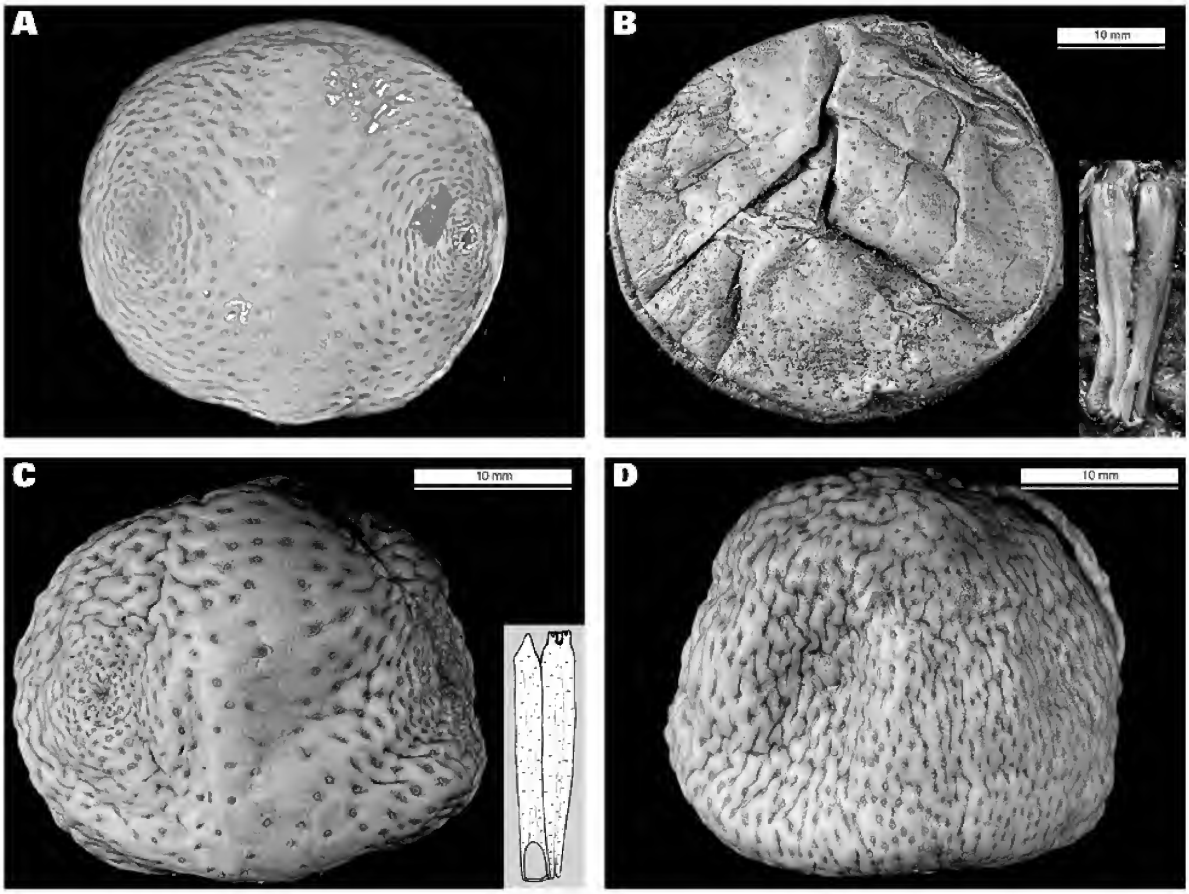

Figure 5. Photos of live and preserved specimens of ***Massinium bonapartum*** O'Loughlin sp. nov. A, dorsal view of live holotype specimen (WAM Z27860); B, lateral view of preserved paratype (NMV F202985, 43 mm long); insert with photo of the calcareous ring of the paratype; C, dorsal view of preserved holotype (30 mm long); insert with sketch of the calcareous ring of the holotype; D, ventral view of the preserved holotype.

with long median un-calcified section; inter-radial plates pointed anteriorly, small oval un-calcified section posteriorly; 1 polian vesicle; gonad tubules long, branched; respiratory trees extending the length of the coelom.

Ossicles in mid-body wall tables only, sparse, scattered, tables abundant in oral disc and peri-anally; table discs oval to round, variable sizes, up to 90 μm long, margin smooth or slightly undulating, not spinous, 4 large central perforations, variable number of smaller outer perforations, some very small; spires rare or reduced, if present 1 or 2 pillars, spires up to half disc length long, few short spines apically. Oral disc with rods as in tentacles and abundant tables with multi-perforate discs and predominantly single pillar spires, discs oval to sub-rectangular, 4 large central perforations, numerous smaller outer perforations, discs up to 96 μm long, spires with 1 or 2 pillars, few short apical spines, length about half disc length. Tube feet with endplates, diameters about 150 μm, lacking support ossicles. Tentacles with rod ossicles only, up to

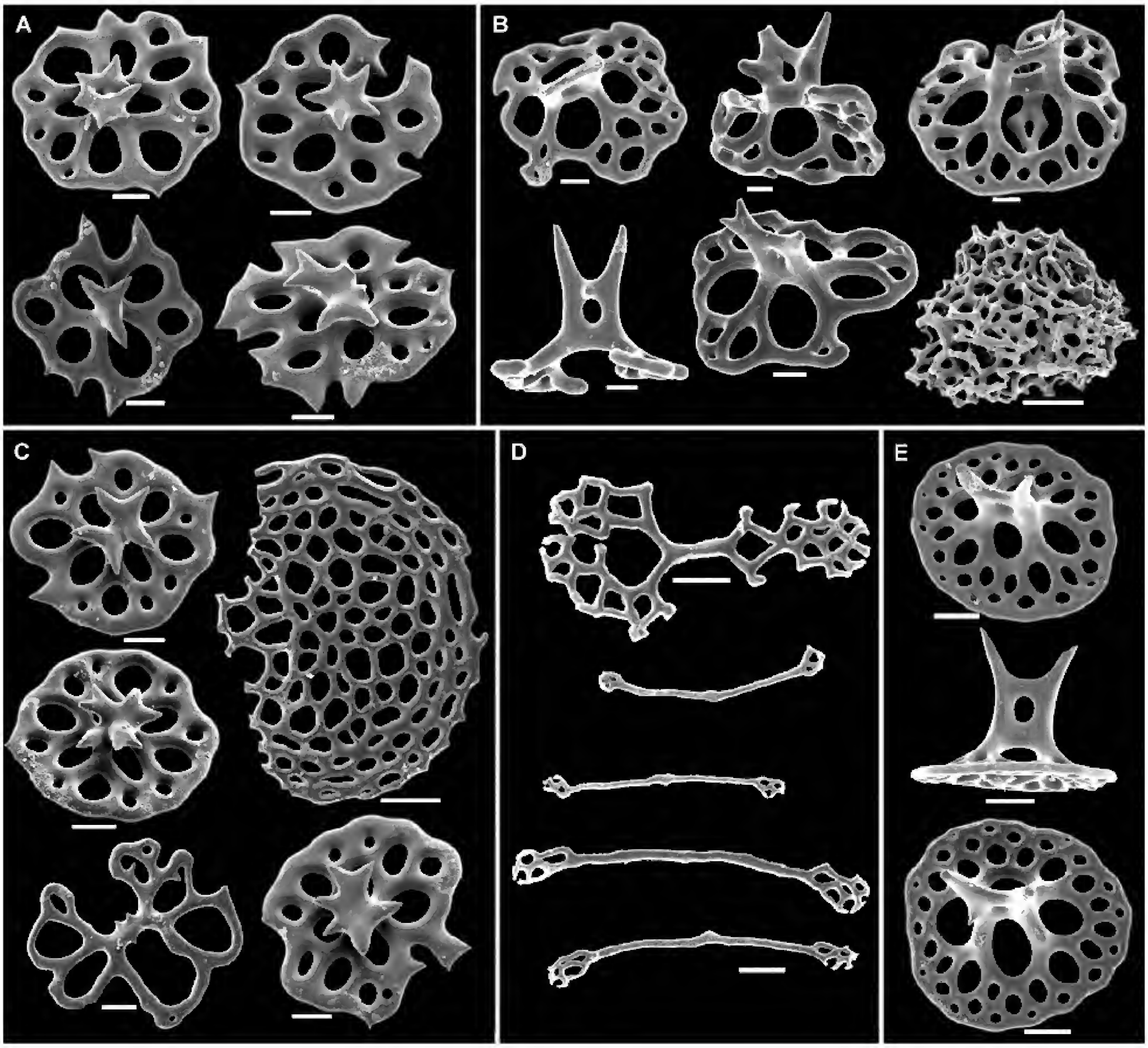

Figure 6. SEM images of ossicles from the holotype of ***Massinium bonapartum*** O'Loughlin sp. nov. (WAM Z27860). A, mid-dorsal body wall tables, spires short with fused pillars (scale bars 20 μm); B, peri-anal body wall scale fragment (bottom right, scale bar 50 μm), and irregular tables with 2 discrete or fused pillars (scale bars 20 μm); C, mid-ventral body wall tables (scale bars 20 μm), and fragment of endplate with thickened margin (scale bar 50 μm); D, tentacle rods and rosette-like rod (scale bars 10 μm); E, oral disc tables, table discs irregularly oval with many perforations, spires with 2 pillars partly fused and with long splayed distal spines (scale bars 20 μm).

90 μm long, smooth, ends widened with few perforations and denticulate margin. Rosette ossicles not observed in tentacles or oral disc or body wall.

Colour preserved off-white; tube feet pale brown.

Distribution. NW Australia, Joseph Bonaparte Gulf, Kimberley region, off King George River, 45 m.

Etymology. Named *keesingi* for John Keesing (CSIRO), the leader of the King George River Expedition, with appreciation of John's gracious and helpful collaboration in our work with the sea cucumber collection.

Remarks. A distinctive character of *Massinium keesingi* O'Loughlin sp. nov. is the frequent presence of table spires with a single pillar. We observed the five pairs of small tentacles to be in an inner ring. *Massinium keesingi* sp. nov. is distinguished from other species in the genus by the combination of morphological characters as detailed in the key.

Triasemperia O'Loughlin gen. nov.

Zoobank LSID. http://zoobank.org:act:5140E273-FE8D-4F8A-A66D-F94B74771FE8

Diagnosis. Dendrochirotid species with mouth anterior, anus posterior, lacking anal teeth; tube feet scattered over body; 20 dendritic tentacles, 15 large, 5 inner small; calcareous ring composite, comprising small calcareous pieces, radial and inter-radial composite plates adjoin to create tubular ring, radial plates elongate with thin posterior distal prolongations adjoining inter-radial plate elongations, radial plates with median division for most of the length, inter-radial plates with deep posterior notch; ossicles throughout the body wall tables, discs triangular, typically with 6 large marginal knobs and 6 small perforations, spires with three pillars; tentacles with rods, rosettes, few tables.

Type species. *Triasemperia stola* O'Loughlin sp. nov. (monotypic).

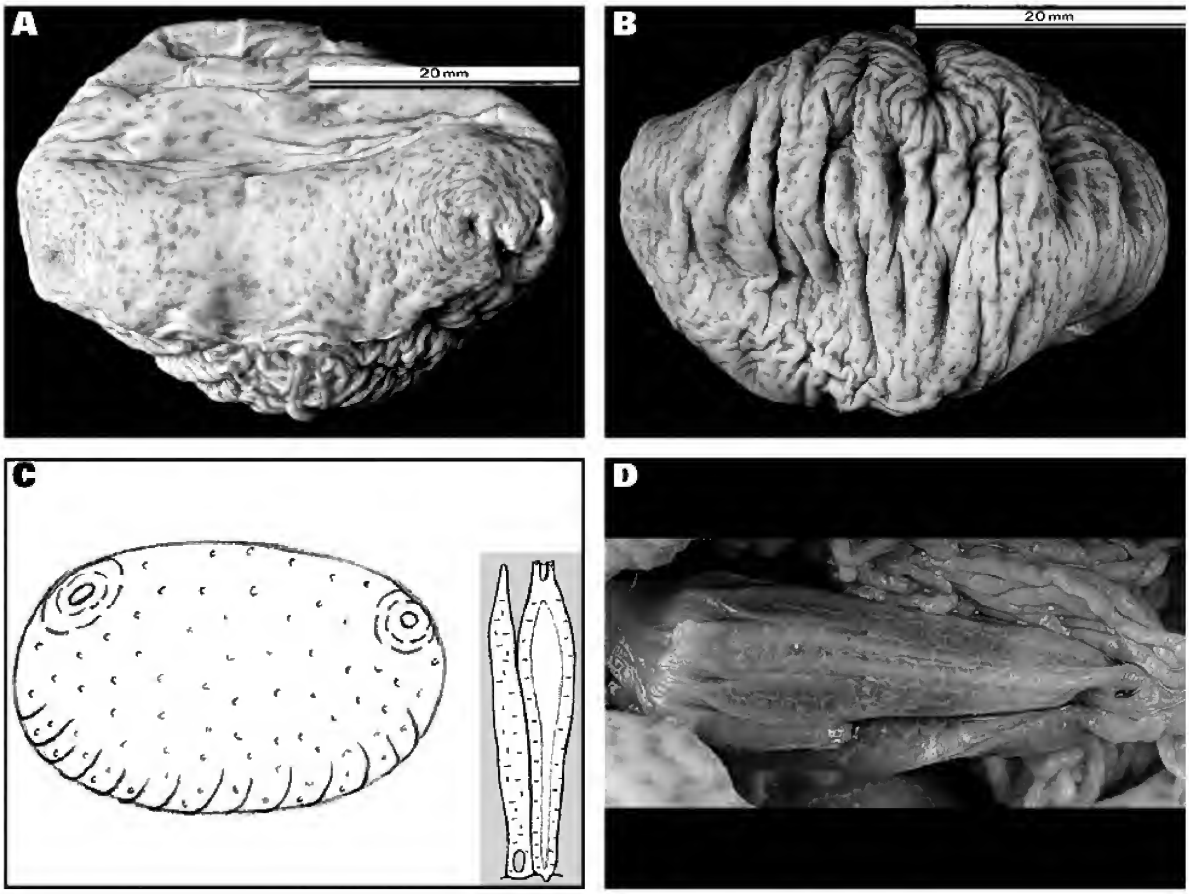

Figure 7. Holotype specimen of ***Massinium keesingi*** O'Loughlin sp. nov. (NMV F203008). A, dorsal view of preserved holotype (40 mm long); B, ventral view of preserved holotype; C, sketch of dorso-lateral view of the holotype; insert with sketch of the calcareous ring; D, photo of the calcareous ring of the holotype.

Etymology. From the Greek *tria* (three), referring to the three pillars of the table spires, with *semperia*, referring to the subfamily Semperiellinae and in turn to the esteemed biologist Carl Gottfried Semper.

Remarks. The new genus *Triasemperia* is referred to the subfamily Semperiellinae on the bases of the presence of 20 dendritic tentacles and composite tubular calcareous ring. The new genus is distinguished from the other genera of the Semperiellinae by the presence of table spires with three pillars.

Triasemperia stola O'Loughlin sp. nov.

Zoobank LSID. http://zoobank.org:act:B8F02EEE-7711-4519-BC96-DE02BD4433F3

Figures 9, 10.

Material examined. Holotype. N Australia, Joseph Bonaparte Gulf, 12.32°S 129.94°E, shell and sand substrate, RV *Solander*, 46 m, AIMS & GA, 5 Aug 2010, NMV F174889 (GA specimen 29084, SOL 5117, 013BS010; UF tissue lot MOLAF1541).

Paratypes. NE Australia, Queensland, Yeppoon, dredged off Middle Island, 23.13°S 150.74°E, 9–37m, B. J. Smith, 6 Sept 1967, NMV F204083 (1); same data, NMV F204088 (1).

Description. Form cylindrical, elongate, upturned oral and anal ends, tapered orally, long taper anally, U-shape up to 45 mm wide (preserved); hard, thick, calcareous body wall, 'prickly' to touch; mouth anterior, anus posterior, lacking anal teeth; tube feet scattered over body, withdrawn, inconspicuous (preserved), diameters about 0.2 mm, paired radial series of tube feet on withdrawn introvert; 20 dendritic tentacles, 15 large, 5 inner small; calcareous ring composite, comprising small calcareous pieces, radial and inter-radial composite plates adjoin to create tubular ring, radial plates elongate with thin posterior distal prolongations adjoining inter-radial plate elongations, radial plates with median division for most of the length, inter-radial plates with deep posterior notch; single polian vesicle; gonad tubules with numerous branches; respiratory trees extending throughout the coelom.

Ossicles throughout body wall densely crowded thick tables, table discs triangular, typically with 6 large marginal knobs and 6 small perforations, discs 80–120 μm wide, spires with 3 pillars and 6 pointed spines distally, disc width and spire height sub-equal. Introvert and tube feet with tables, rods, endplates; tables smaller, irregular, some lacking spires, perforations up to 19, discs up to 56–104 μm wide; smooth rods with distal ends

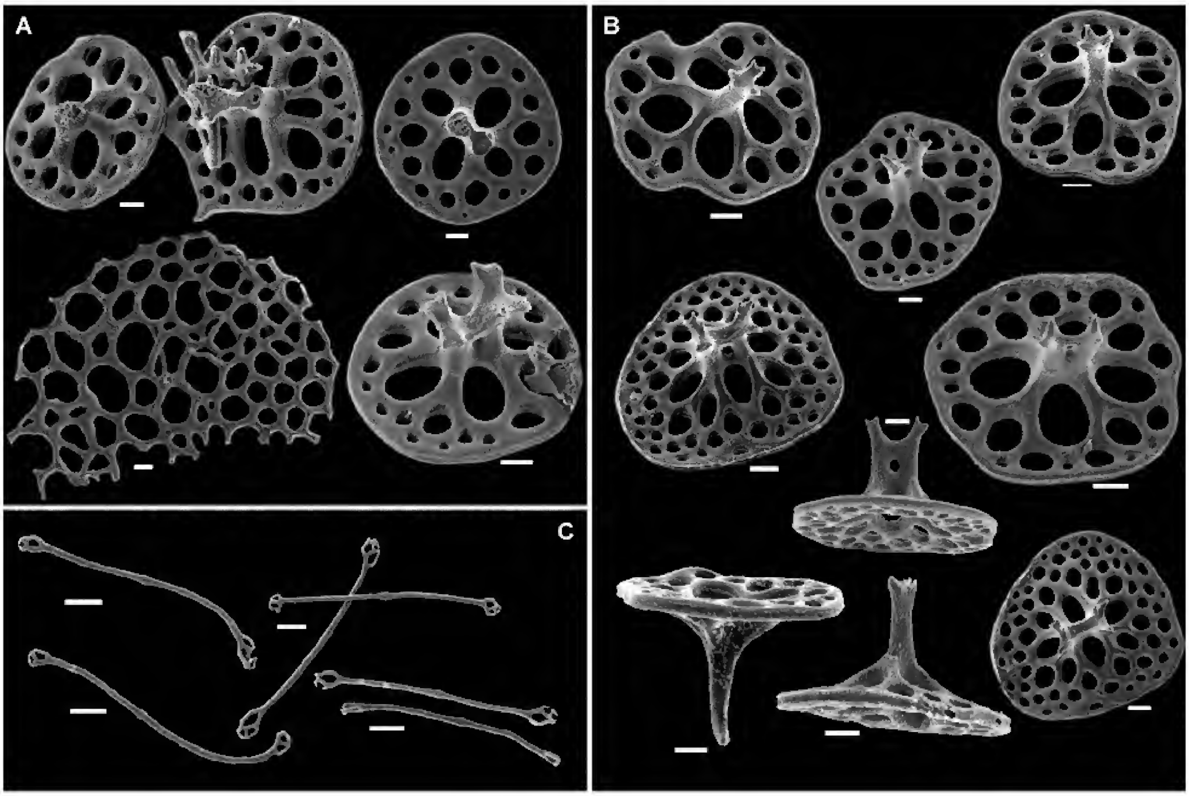

Figure 8. SEM images of ossicles from the holotype of ***Massinium keesingi*** O'Loughlin sp. nov. (NMV F203008). A, peri-anal body wall tables and endplate fragment, discs with smooth margins, spires with 1 or 2 pillars (scale bars 10 μm); B, oral disc tables, table discs with smooth margin, spires with single or 2 partly fused pillars, apical spines short and blunt (scale bars 10 μm); C, tentacle rods (scale bars 10 μm).

enlarged and perforated, up to 120 μm long; endplates with diameters about 136 μm, tube foot support ossicles tables only. Tentacles with rods, rosettes, tables; fine to thick smooth rods with swollen perforated ends; tables rare, form regular or irregular, some not knobbed, discs up 96 μm wide.

Live colour red-brown to brown, preserved colour brown to off-white with residual violet colouration.

Distribution. Northern Australia, from Joseph Bonaparte Gulf to Yeppoon Queensland, 9–53 m.

Etymology. Named *stola* with reference to the genus *Stolus* that has species with heavily knobbed button-like ossicles that are similar to the table discs of this species.

Remarks. The distinguishing morphological character of *Triasemperia stola* is the presence of table spires with three pillars. The calcareous ring and ossicles are similar to those of *Stolus crassus* Liao and Pawson, 2001, but *S. crassus* from the South China Sea is described as having 10 tentacles and only 2 pillars in the table spires.

Family **Thyonidiidae** Heding and Panning, 1954 (*sensu* Smirnov 2012)

Remarks. Heding and Panning (1954) initially described the Thyonidiinae as a sub-family within the Phyllophoridae Östergren, 1907. Based on the absence of posterior segmented prolongations on the calcareous ring Pawson and Fell (1965) transferred the Thyonidiinae to a sub-family within the Cucumariidae Ludwig, 1894. Based on the presence of more than 10 tentacles and table ossicles Smirnov (2012) raised Thyonidiinae to family status as Thyonidiidae. The plate ossicles in *Parathyonidium* Heding (in Heding and Panning), 1954 and "reduced" ossicles in *Athyonidium* Deichmann, 1941 and *Patallus* Selenka, 1868 suggested to Smirnov (2012) that these genera were probably unrelated to the genera with tables.

Actinocucumis Ludwig, 1875

Actinocucumis Ludwig, 1875: 91.—Théel, 1886: 125.—H. L. Clark, 1946: 402–403.—Heding and Panning, 1954: 70–72.—A. M. Clark and Rowe, 1971: 204.

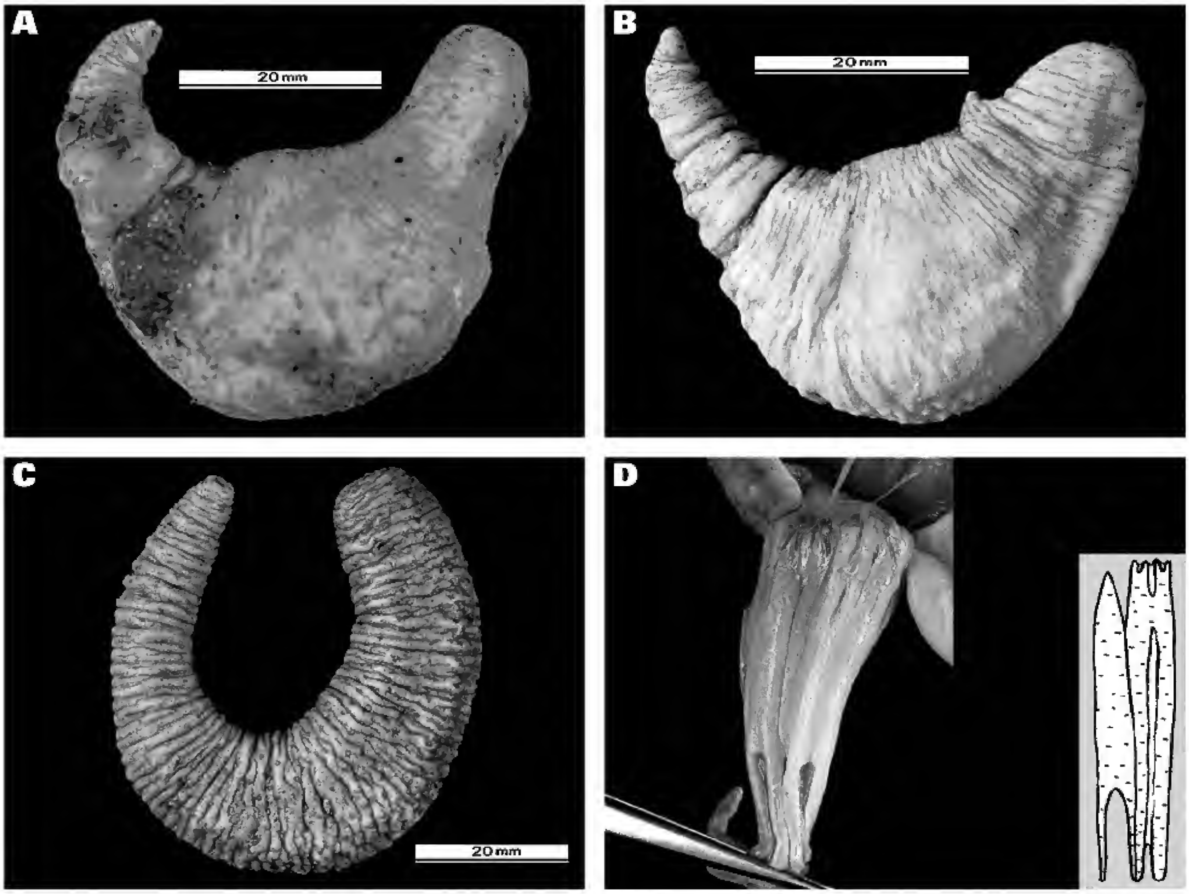

Figure 9. Photos of live and preserved specimens of ***Triasemperia stola*** O'Loughlin sp. nov. A, lateral view of live holotype specimen (mouth right; NMV F174889); B, lateral view of preserved holotype (mouth right, lateral view width 45 mm); C, lateral view of preserved paratype (mouth right, lateral view width 50 mm, NMV F204088); D, photo of the calcareous ring of the holotype; insert with sketch of the calcareous ring.

Type species. *Actinocucumis typica* Ludwig, 1875 (type locality Queensland, Bowen, 20°S 148°E)

Other species and type localities. *Actinocucumis chinensis* Liao and Pawson, 2001 (off Hainan, South China Sea); *A. cornus* (Heding, 1934) (Hong Kong); *A. difficilis* Bell, 1884 (Torres Strait, north-east Australia); *A. longipedes* Clark, 1938 (Broome, north-west Australia); *A. simplex* (Sluiter, 1914) (Indonesia); *A. solanderi* O'Loughlin sp. nov. (off King George River, northern Australia) (see below).

Remarks. Heding and Panning (1954) listed numerous synonymies for *Actinocucumis typica*, with lengthy discussion. We have not examined the relevant type specimens but based on the figures and descriptions in the literature, and on our *sensu stricto* diagnosis of *A. typica* below, we raise all of these species out of synonymy.

We note that in discussing their synonymies Heding and Panning (1954) observed in their slide preparations from *Actinocucumis typica* and *Actinocucumis cornus* specimens small elongate plates with two long mid-plate perforations and two small distal ones. This form of ossicle was illustrated by H. L. Clark (1938) for *Actinocucumis longipedes*. Ludwig (1875) did not illustrate this form of ossicle and we have never observed such ossicles in our preparations from specimens of *A. typica* from the region of the type locality and across northern Australia. It appears to us that Heding and Panning were not examining specimens of *A. typica*.

Two ossicles are drawn for *Actinocucumis typica* in Clark and Rowe (1971; fig. 95 e and e'). We have seen only the left

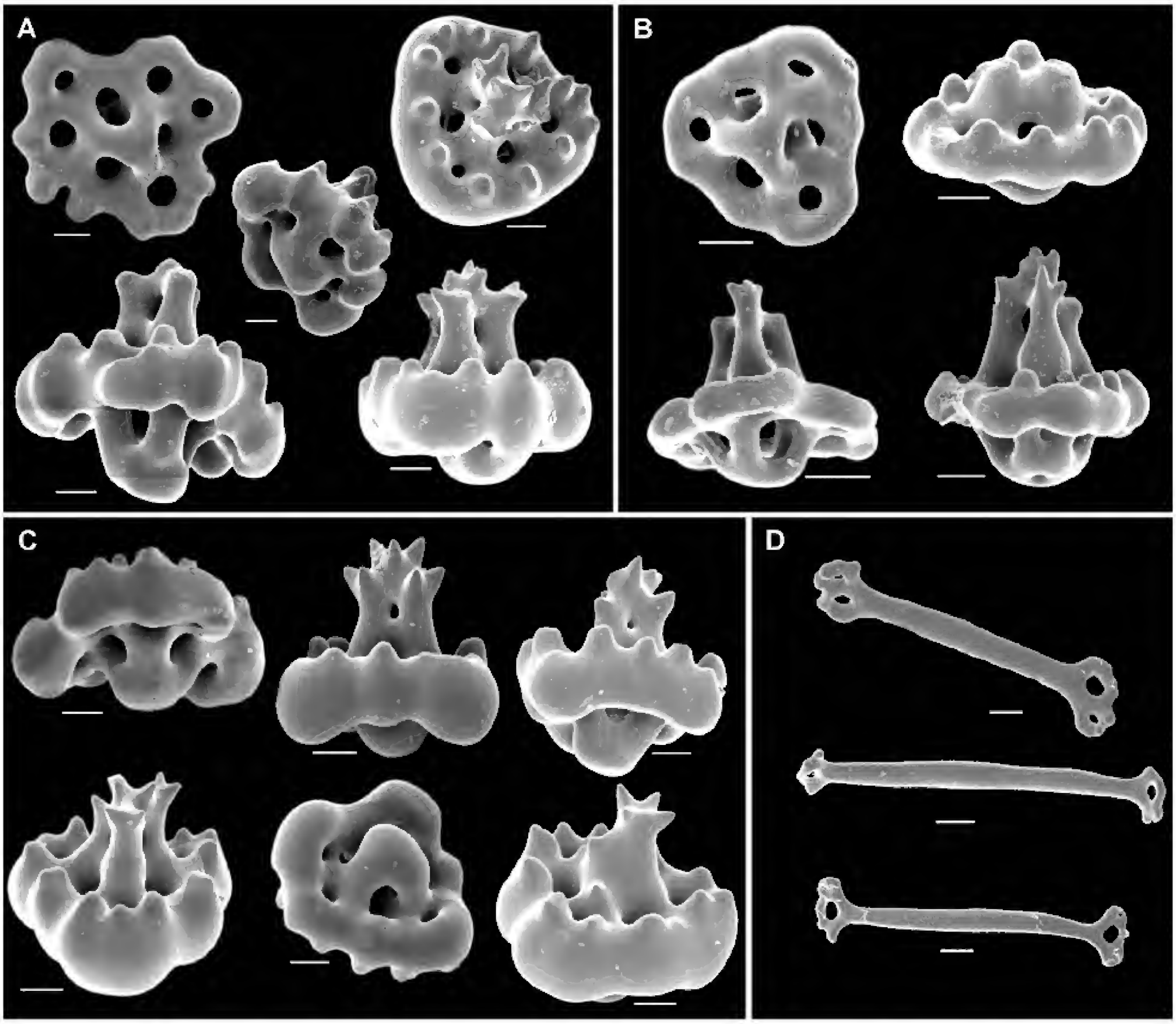

Figure 10. SEM images of ossicles from the holotype of ***Triasemperia stola*** O'Loughin sp. nov. (NMV F174889). A, mid-dorsal body wall tables, spires with 3 pillars (scale bars 20 μm); B, peri-anal body wall tables (scale bars 20 μm); C, tube foot tables (scale bars 20 μm); D, tentacle rods (scale bars 20 μm).

hand side form (e) in the specimens of *A. typica* that we have examined, and this is the only form in the original description by Ludwig (1875). The right hand side form (e') appears to be typical of *Actinocucumis longipedes* and was referred to by Heding and Panning (1954) above. The two ossicle forms appear to have been drawn from a specimen of *A. longipedes*.

We note that the Clark and Rowe (1971) illustration of ossicles from *A. typica* (pl. 30 fig. 4) is in fact from a type specimen of *Actinocucumis difficilis* Bell that was judged to be a con-specific with *A. typica*. The ossicles appear to us to exemplify *A. typica*, and that adds weight to the probability of a synonymy (NHMUK type information confirmed by Andrew Cabrinovic). There are no small elongate plates with two long mid-plate perforations and two small distal ones in this preparation.

The single type specimen from Hong Kong of *Phyllophorus cornus* Heding, 1934 has tube feet all over the body, five inner tentacles and 15 outer, and five anal teeth. Ossicles from the type of *Actinocucumis cornus* were used for the illustration in Heding and Panning (1954, fig. 19) of the ossicles of *A. typica*. The original illustration of ossicles for *A. cornus* (Heding 1934) did not show fenestrated ellipsoids. That in Heding and Panning (1954) did show fenestrated ellipsoids. Neither illustrated the small plates with two long and two small distal perforations that Heding and Panning (1954) indicated were present. We judge that the status of *A. cornus* as conspecific with *A. typica* remains uncertain, and we raise it out of synonymy as an *Actinocucumis* species.

Pseudocucumis quinqangularis Sluiter, 1901 from Indonesia has posterior prolongations on the radial plates of a composite calcareous ring, 12 large outer and six small inner tentacles, and an absence of figure-8 ossicles and fenestrated ellipsoids. It is not a species of *Actinocucumis* and we raise the species out of synonymy in the original combination to await further study.

The single small type specimen from Ceylon of *Actinocucumis donnani* Pearson, 1903 does not have the tentacles present, has a composite calcareous ring with long posterior prolongations on the radial plates, and has body wall ossicles that are not fenestrated ellipsoids or any form of table. It is not an *Actinocucumis* species. In the absence of tentacles it is not possible to re-assign the species that we regard as *incertae sedis*.

The illustrations for *Phyllophorus simplex* Sluiter, 1914 indicate ossicles that do not include fenestrate ellipsoids and typical figure-8 plates, and the description reports tube feet covering the body. It is not conspecific with *Actinocucumis typica*, and we raise it out of synonymy with reservations as an *Actinocucumis* species.

H. L. Clark (1938, 1946) examined numerous specimens of *Actinocucumis* from northern Australia and was convinced of the existence of four species: *A. typica*, *A. difficilis*, *A. longipedes*, *A. quinuangularis*. We reject *A. quinuangularis* as an *Actinocucumis* species (above), but accept the judgment by Clark who recognized the other three species. We raise *A. difficilis* and *A. longipedes* out of synonymy here. In the case of *A. difficilis* we defer to the experience of H. L. Clark (1938, 1946) who had an abundance of material to examine, but we also judge that the morphological characters that he used to distinguish this species are probably variable characters. We think that a confirmed synonymy requires more consideration. The presence in *A. longipedes* of small elongate plates with two long mid-plate perforations and two small distal ones is apparently systematically distinctive.

We note the absence of fenestrated ellipsoids and radial papillae in *Actinocucumis chinensis* and continue to refer this species to *Actinocucumis* with reservation, as did Liao and Pawson (2001).

Actinocucumis typica Ludwig, 1875

Actinocucumis typica Ludwig, 1875: 91, fig. 24 a–d.—Lampert, 1885: 177.—Théel, 1886: 84, 125, pl. 12 figs 4, 5.—Ludwig, 1888: 817.—Erwe, 1913: 364–365, pl. 6 fig. 10a, b.

Actinocucumis typicus.—H. L. Clark, 1921: 170.—Clark, 1938: 479.—Clark, 1946: 403.—Heding and Panning, 1954: 72–74, figs 19, 20 (part).—A. M. Clark and Rowe, 1971: fig. 95 e, pl. 30 fig. 4 (part).—Liao and Clark, 1995: 481–482, fig. 290, pl. 23 fig. 10 (part).

Material examined. NE Australia, Queensland: Yeppoon, dredged off Middle Island, 23.13°S 150.74°E, 9–37m, B. J. Smith, 6 Sept 1967, NMV F204078 (1); Mackay harbour, 21.15°S 149.18°E, Ian Kirwan, 14 Jul 1982, NMV F206362 (1); near Cairns, Machans Beach, 16.85°S 145.73°E, on beach after cyclone, B. Collins, 25 Dec 1996, NMV F203016 (2); N Australia, Joseph Bonaparte Gulf, 11.55°S 129.82°E, RV *Solander*, 48 m, AIMS & GA, 26 Aug 2010, NMV F173265 (1) (GA lot SOL5117 lot 082BS040; UF tissue lot MOLAF1552); NW Australia, Dampier Archipelago, 1.3 km E of Eaglehawk I., FRV *Flinders*, DA2/73/01, 20.67°S 116.46°E, coarse sand, 13 m, 24 Jul 1999, NMV F209501(1).

Diagnosis (sensu stricto). Dendrochirotid species, uniform brown colour (NMV F204078), or yellowish brown with some red patches and fine black flecking (NMV F173265), or pale brown to cream with fine brown flecking on body and larger brown patches on tube feet (NMV F206362); body pentagonal in section with raised radial ridges; five thick oral valves; about 20 dendritic tentacles, variable in arrangement and size, ventral pair smallest; tube feet confined to radii, small papillae and tube feet also on radii and encroaching inter-radially; tube feet in 4–6 rows (80 mm long specimen, Ludwig 1875), or in paired rows (smaller 35–44 mm long specimens, this work); calcareous ring not composite, radial plates with vertical sides, radial and inter-radial plates lacking posterior prolongations.

Body wall ossicles abundant, crowded, small plates and ellipsoids, and rare, thick large plates; bi-perforate plates (figure-8 form, "acorn" plates in Ludwig 1875 and Clark 1938, 1946) predominate, up to about 40–50 μm long with one central and 5 marginal knobs, the apical knob typically projecting; bi-perforate plates inter-grade with abundant but less numerous irregularly ovoid fenestrated ellipsoids, up to about 40–55 μm long; large plates thick, irregular in outline, perforation sizes irregular, plates frequently more than 150 μm long. Tube feet with endplates and support tables; large endplate diameters about 240 μm, small endplate diameters about 120 μm; table discs elongate, up to 160 μm long, narrow, widened centrally and distally, spires with 4-pillar base, pillars frequently joined to form an arch, arches frequently with single, long, thick, pointed, apical spine. Introvert with abundant tables, spires with four-pillar base and pillars fused with distal narrow arch or long spine or 2 short blunt spines. Papillae with body wall ossicles, rare tables, and lacking endplates. Lacking anal scales.

Remarks. Because uncertainty remains about the assignment of species to this genus we provide a *sensu stricto* diagnosis of *Actinocucumis typica*, based on the morphological characters of the type species. We examined six northern Australian specimens of *Actinocucumis* (listed above). We confidently judge that four of these specimens are *Actinocucumis typica* as all of their morphological characters closely fit the original description and illustrations by Ludwig (1875). These characters are detailed in the generic diagnosis above. With less confidence we judge that the two beach-washed specimens are also *A. typica* (NMV F203016).

The ossicles of specimens from the Philippines that are illustrated by Reyes-Leonardo et al. (1985) appear to us to be close to those illustrated for *Actinocucumis longipedes*, although the description refers to the presence of fenestrated ellipsoids and irregular tables with pointed spires. The descriptive reference to "wart-like" podia scattered all over the body" is not characteristic of *A. typica*.

Actinocucumis solanderi O'Loughlin sp. nov.

Zoobank LSID. http://zoobank.org:act:804F4A5E-37B6-441B-BBC7-BBA118E61036

Figures 11, 12.

Material examined. Holotype. N Australia, Joseph Bonaparte Gulf, 13.82°S 127.32°E, 73 m, 12 Jun 2013, WAM Z27850 (KGR specimen 29384; UF tissue lot MOLAF1438).

Paratype. Joseph Bonaparte Gulf, 11.04°S 129.81°E, RV *Solander*, 52 m, Geoscience Australia, 9 Jun 2009, NMV F202991 (1) (GA lot SOL4934 lot 23BS14; UF tissue lot MOLAF1508).

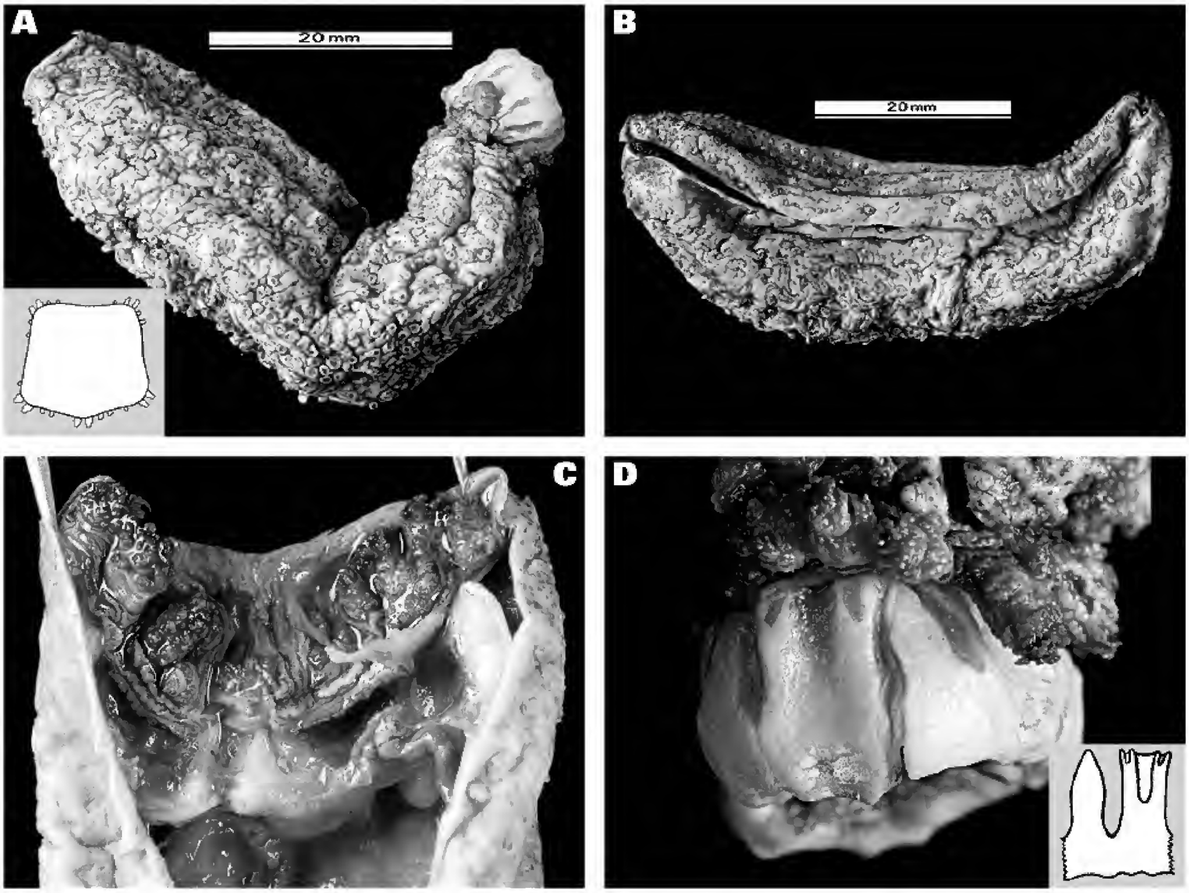

Figure 11. Photos of preserved specimens of ***Actinocucumis solanderi*** O'Loughlin sp. nov. A, right lateral view of the preserved holotype (mouth right, 45 mm long, WAM Z27850); insert with sketch of a transverse section of the new species showing slight radial ridges and large and small tube feet and papillae; B, right lateral view of the preserved paratype (mouth left, 55 mm long, NMV F202991); C, dorsal view of tentacle crown with small tentacles ventrally (paratype NMV F202991); D, photo of the calcareous ring of the holotype; insert with sketch of the calcareous ring.

Description. Form elongate, sub-cylindrical, slightly pentagonal with raised radial ridges tending to create 5 oral and 5 anal valves, mouth anterior, anus posterior, slightly tapered and up-turned orally and anally, up to 55 mm long (preserved); hard, thick, calcareous body wall; 20 dendritic tentacles, about 10 large dorsally, about 10 small ventrally; tube feet conspicuous, extended, predominantly on radii in irregular paired series, largest in mid-body on radii, diameters about 1.0

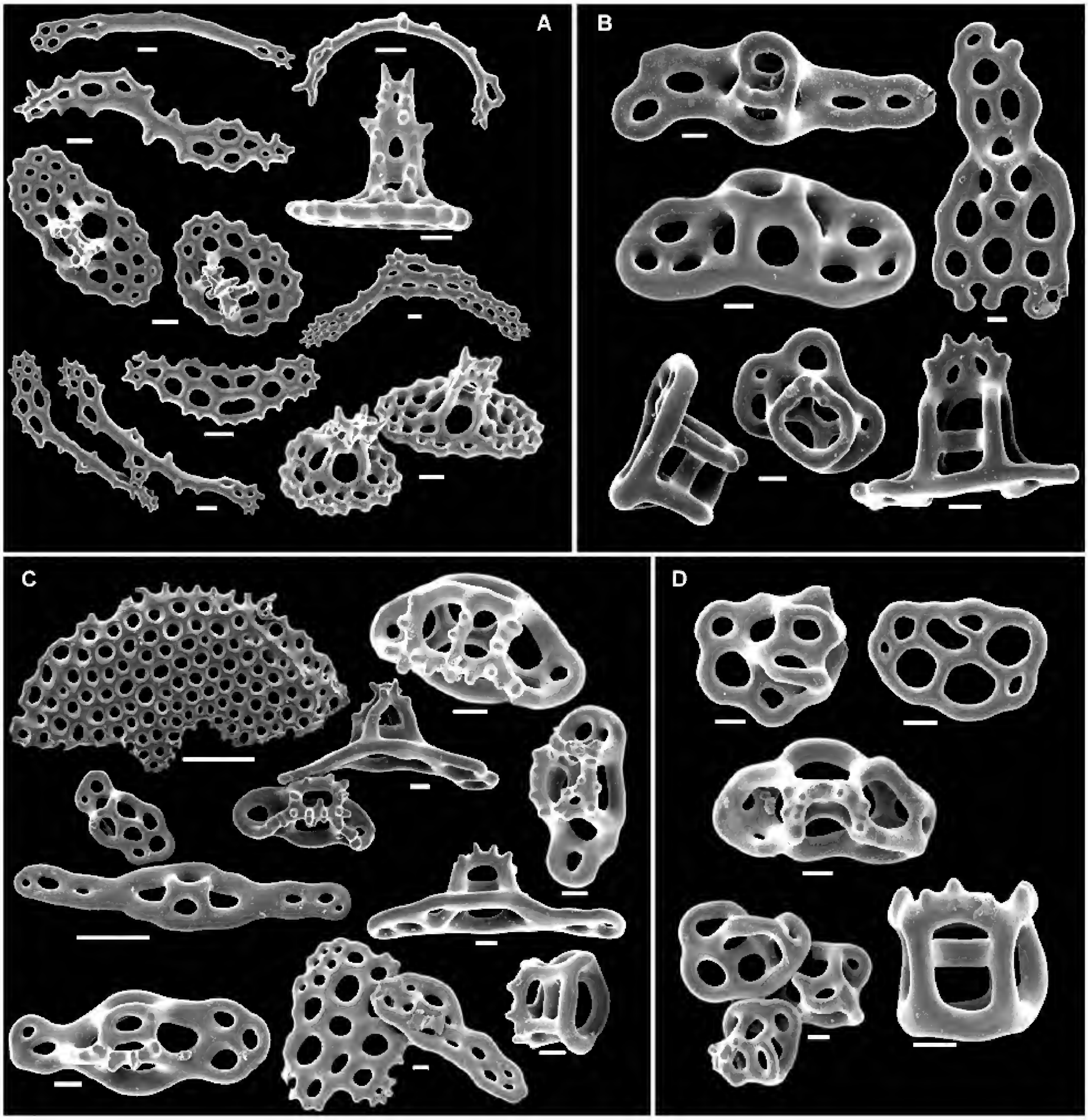

Figure 12. SEM images of ossicles from the holotype of ***Actinocucumis solanderi*** O'Loughlin sp. nov. (WAM Z27850). A, oral disc and tentacle tables, spires with 4 pillars, and tentacle rods and curved perforated rod-plates (scale bars 10 μm); B, mid-dorsal body wall reduced tables with four pillar spires (scale bar 10 μm); C, mid-ventral body wall tables, and tube foot elongate support tables and endplate fragment (two top left long scale bars 100 μm, short bars 10 μm; typical box-like table bottom right); D, peri-anal body wall reduced tables (scale bars 10 μm; typical box-like table bottom right).

mm, small tube feet (with endplates) and papillae (lacking endplates) on radii and encroaching on inter-radii, diameters about 0.3 mm; lacking anal scales; calcareous ring comprising non-fragmented radial and inter-radial plates, lacking posterior prolongations, radial plates sub-rectangular with larger anterior median notch and smaller lateral notches, inter-radial plates with long anterior taper to blunt point; single polian vesicle; gonad tubules with multiple branches; respiratory trees extending throughout the coelom.

Ossicles throughout the dorsal, ventral and peri-anal body wall are densely crowded small, thick irregular tables and reduced tables, and large, elongate smooth perforated plates; tables frequently box-like with round disc about 30–40 μm wide with single perforation, disc width similar to spire height, spires about 25–35 μm high with 4 pillars joined mid-spire and apically, short blunt spines apically, tables often reduced with incompletely formed and irregular disc and spire; body wall tables inter-grade in form with elongate tube foot support tables; perforated plates numerous in body wall, surface and margin smooth, up to about 240 μm long. Tentacles with tables, rods and rod-plates, lacking rosettes; table discs irregularly round to elongate oval, central disc single perforation and few large or many small outer perforations, disc margin undulating to denticulate, discs up to about 80 μm long, spires well-developed with four-pillar base, blunt spines distally and sometimes along spire, spires up to 50 μm high; curved rods perforated along rod, margin denticulate; rod-plates thick, wide, perforate distally, sometimes bifid distally, up to 440 μm long. Tube feet with endplates about 450 μm in diameter; tube foot support ossicles elongate tables with narrow curved discs up to 450 μm long and four pillar spires variably developed. Introvert with abundant tables as in tentacles.

Colour preserved off-white to grey to pale brown with a hint of residual crimson dorsally, dark brown to black small spots spaced all over body; tube feet off-white with brown disc.

Distribution. N Australia, Joseph Bonaparte Gulf, 52–73 m.

Etymology. Named for the research vessel of the Australian Institute of Marine Science, the RV *Solander*, from which the King George River expedition and cruise SOL 4934 were conducted and these type specimens collected.

Remarks. The distinguishing morphological character of *Actinocucumis solanderi* O'Loughlin sp. nov. is the presence in the body wall of abundant small, thick, box-like tables and tables that are reduced to varying degrees.

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A new genus and species of Calocidae (Trichoptera: Insecta) from south eastern Australia

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Abstract

Shackleton, M.E., Webb, J.M., Lawler, S.H. and Suter, P.J. 2014. A new genus and species of Calocidae (Trichoptera: Insecta) from south eastern Australia. *Memoirs of Museum Victoria* 72: 25–30.

Latarima gen. nov. (Trichoptera: Calocidae) is described from southeastern Australia based on the male adult, male pupa, and larva. Two species are included, *L. explicatala* sp nov. and *L. furcilla* (Neboiss, 1984a) comb. nov. Males of *Latarima* gen. nov. are distinct from other Calocidae genera in that segment X of the genitalia is widely incised, forming two elongate sections on the segment. Larvae are distinguished by a reticulate texture of the head capsule and a frontoclypeus that widens suddenly towards the anterior and possesses many setae in the antero-lateral corners. Larvae were previously placed in the interim genus Cal/Hel Genus G by Jackson (1998). This work increases the number of Calocidae genera to 7.

Keywords

Latarima gen. nov., *explicata* sp. nov, *Tamasia furcilla*, Pupa, Larva.

Introduction

There are currently 6 recognised genera in the family Calocidae Ross, with 5 occurring in Australia and 1 monotypic genus in New Zealand. Mosely (1936) described the first genus *Tamasia* Mosely, 1936, which contained a single species *Tamasia variegata* Mosely, 1936. It was originally placed in the family Sericostomatidae, Stephens. Mosely and Kimmins (1953) later described seven new species from three new genera, also placed in the family Sericostomatidae, that would later be included in the family Calocidae. These were *Caenota plicata* Mosely, in Mosely and Kimmins 1953, *Caenota simulans* Mosely, in Mosely and Kimmins 1953, *Caloca straminea* Mosely, in Mosely and Kimmins 1953, *Caloca tertia* Mosely, in Mosely and Kimmins 1953, *Caloca eba* Mosely, in Mosely and Kimmins 1953, and *Caloca fallia* Mosely, in Mosely and Kimmins 1953. A further species, *Tismana saneva* Mosely, in Mosely and Kimmins 1953, was placed in the Odontoceridae and later synonymised with *Caloca* by Neboiss (1977).

The name Calocidae was established by Ross (1967) presumably to accommodate these seemingly related genera: *Caenota* Mosely, 1953, *Caloca* Mosely, 1953, and *Tamasia*. In his publication, Ross (1967) gave no indication of the genera to be included in the family but stated that the leg spur formula was 2:2:4 and that Calocidae were similar to ancestor 15 (Neboiss 1977; Jackson 1991; Holzenthal et al. 2007). Johanson and Malm (2010) indicate that the family name is derived from *Caloca* suggesting the inclusion of this genus.

The New Zealand endemic, monotypic genus, *Pycnocentrella* Mosely, 1953, was originally described in Mosely and Kimmins (1953) and placed in the family Baeridae. Ross (1967) established the family Pycnocentrellidae Ross, again without indicating which genera it contained. However, *Pycnocentrella* can be assumed to be included. *Pycnocentrella* was transferred to Calocidae by Neboiss (1977).

Neboiss (1984a) added two new species to the genus *Tamasia*, *T. acuta* Neboiss, 1984a, and *T. furcilla* Neboiss, 1984a. In the same year two further genera were described in the Calocidae in Neboiss (1984b). These were *Calocoides* Neboiss, 1984b, with a single species and *Pliocaloca* Neboiss, 1984b, with three species, all from northern Queensland.

The taxonomy of the family is based on characters of the adult males. Until recently, the larvae of only 5 species from four genera were known: *Caloca saneva*, *Caenota plicata*, *Pycnocentrella eruensis* Mosely, 1953, *T. variegata*, and *T. acuta*. These were illustrated in Jackson (1998), along with a number of larval types which she considered likely to be distinct genera. Jackson (1998) gave these the temporary generic names Genus Cal/Hel A – H. The genus name Cal/Hel reflected her uncertainty as to whether these taxa belonged to the family Calocidae or Helicophidae. Neboiss (2002) associated the larva of the monotypic Genus Cal/Hel A with a newly described species, *Heloccabus buccinatus* Neboiss, 2002, that he tentatively placed in the family Helicophidae. The taxa Genus Cal/Hel B, C, and D have recently been associated with known and newly described species, each in separate genera (Cal/Hel B and C, Shackleton, in prep; Cal/Hel D, Shackleton and Webb, 2014). All genera described to date can easily be distinguished through examination of larval characters.

The current study provides descriptions of the adult male and pupa of a new species and genus, *Latarima* gen. nov. *explicatala* sp. nov, which is associated with the larva that Jackson (1998) referred to as Genus Cal/Hel G. The presence of male genital characters on a pharate male pupa, along with the sclerites of the larva, which are exuviated and retained in the posterior of the pupal case, enables an association between the life stages of the species (Milne 1938). Similarities in adult male characters between this species and that of *Tamasia furcilla* suggest a close relationship between the two. Here we suggest that these two species belong in the new genus, *Latarima* gen. nov. This work increases the number of Calocidae genera to 7.

Materials and Methods

Adult, larval and pupal specimens were obtained from the Museum of Victoria, Melbourne, and the Environmental Protection Authority, Victoria. All specimens are deposited in the Museum of Victoria, Melbourne.

Larval sclerites were extracted from pupal cases and compared with known larvae. Similarities in the genitalia of pharate male pupae were used to associate the adult with the pupal form.

Material was examined using a Nikon SMZ1500 microscope. Photographs were taken using a Nikon DS-Fi1 camera mounted on a Nikon SMZ1500 microscope. Helicon Focus 5.3.7 was used to create photographs with a wide depth of field. Photographs were edited using GIMP 2.6.11.

Terminology of the adult characters follows that of Mosely (1936), Neboiss (1991, 1992), and Holzenthal et al. (2007). Terminology of the larval characters follows that of Jackson (1998). Terminology of pupae follows that of Holzenthal et al. (2007). Because the modification of the hind wing venation of this species makes identification of individual veins difficult, the author's interpretation of the wing venation is indicated on the illustrations provided.

Family **Calocidae**

Latarima Genus nov.

Zoobank LSID. http://zoobank.org/urn:lsid:zoobank.org:act:955AF7F6-958F-4485-AC37-80DD885EE461

Type species: ***L. furcilla*** (Neboiss) comb. nov. (***Tamasia furcilla*** Neboiss in Neboiss 1984a).

Generic Diagnosis. Adult and larval characters can be used to distinguish *Latarima* from all other Calocidae genera. This genus is the only Calocidae genus known where segment X, in the adult males, is widely separated at the base of the segment. The dorsal surface of the head capsule, in the adult male, does not possess eversible scent organs, as in *Caloca* and *Pliocaloca*. The segments of the maxillary palps are expanded, similar to *Tamasia, Caenota,* and *Pycnocentrella*. However, unlike *Caenota*, segments 3 and 4 are not greatly reduced. As with *Tamasia*, but no other Calocidae genus, there are only 4 maxillary palpal segments.

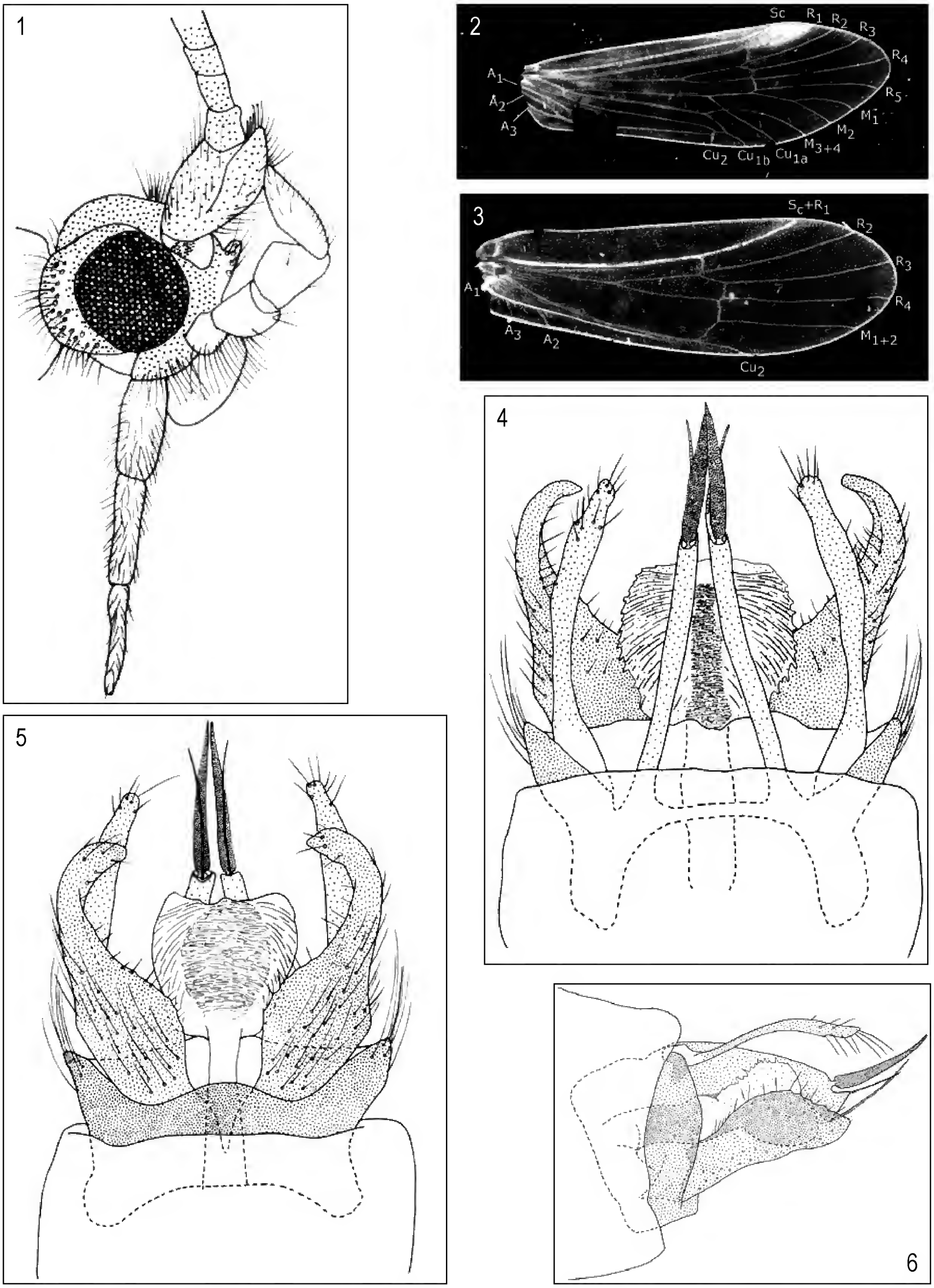
In the larva, the frontoclypeus widens suddenly towards the anterior margin, unlike those of *Caloca*, *Tamasia*, and *Calocoides*. The posterior and anterior portions of the frontoclypeus are separated by a constriction and the lateral margins of the anterior portion are somewhat rounded. This is dissimilar to *Pycnocentrella eruensis* where the anterior portion diverges out from the posterior portion in a straight line without any constriction between the two. The head and pronotum is reticulate in texture and does not possess the dense, short, papillate setae present in *Tamasia* or *Pliocaloca*. The metanotum does not possess a small, sclerotised ridge on the anterior margin, as in *Caenota* and *Calocoides*. The foretrochantin is fused to the propleuron, unlike that of *Pliocaloca*.

Generic description. Adult male: Dark brown to blackish, white markings on wings. Head: dorsum with single setal wart along midline; small receptacle on posterior margin dorsally extending mid-dorsal setal wart, not membranous, without eversible scent organs; posterior setal warts absent; postocular setal warts long, narrow. Maxillary palps four segmented, segments irregular, bulbous, apical segment reflexed posteriorly; labial palps three segmented; antenna slightly shorter than fore wing; scape long, with highly setose anterior projection. Pronotum: one pair lateral setose warts. Mesoscutellum smooth. Scutellum with one pair, elongate, setal warts. Legs: tibial spines 2:2:4. Wings: Forewing: discoidal cell present; thyridial cell present; fork 1 and 2 sessile; fork 3 petiolate; fork 4 absent; fork 5 sessile or slightly petiolate. Hind wing: venation reduced, with or without posterior fold; discoidal cell present; thyridial cell absent; base of M absent; large vein-free area in basal posterior section if no fold present; Sc and R1 fused; cell formed by Sc and C relatively large; fork 1 sessile, no other forks present. Genitalia: Segment X divided into two elongated, widely separated segments.

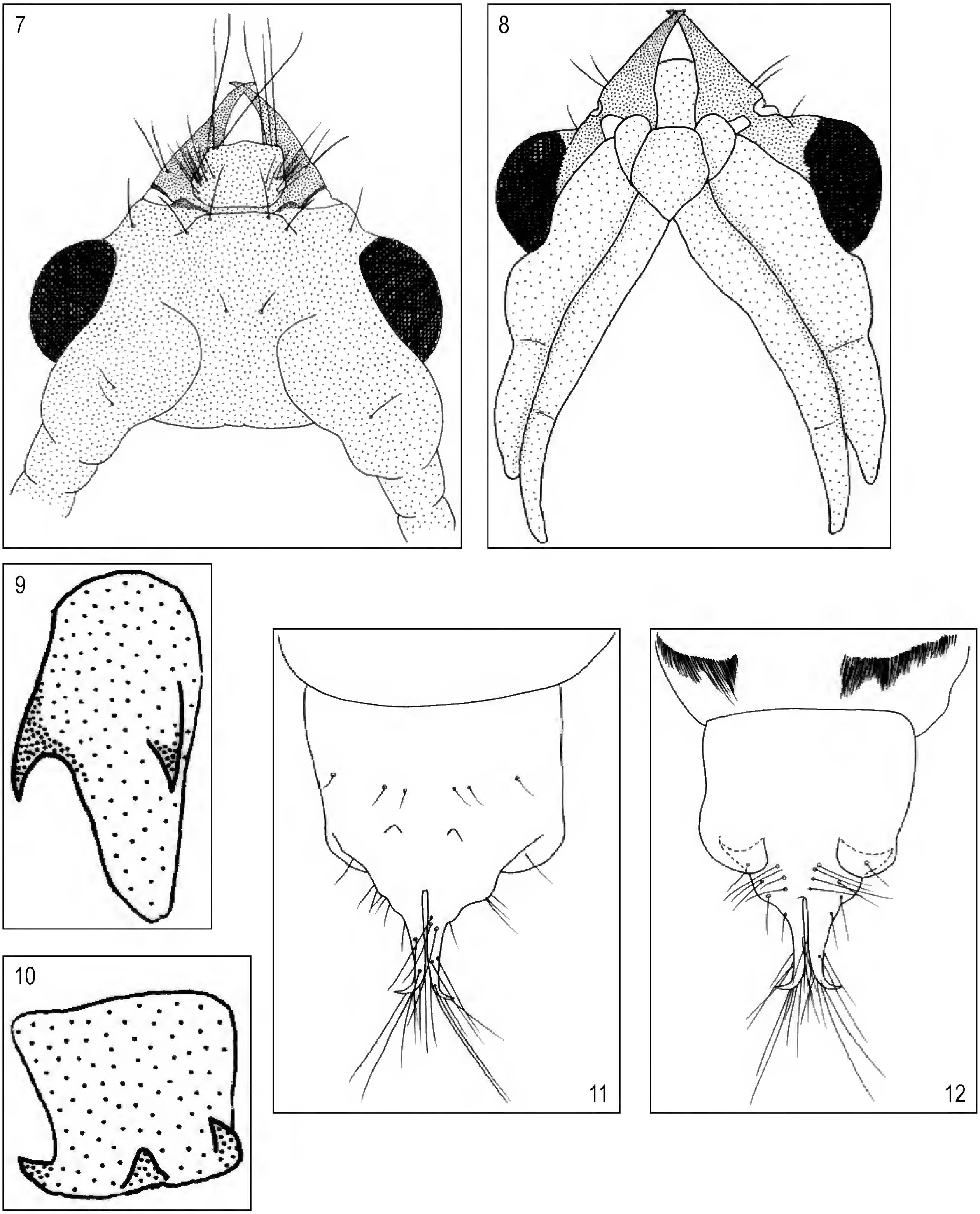
Larva: Head: reticulate in texture; frontoclypeus widens suddenly anteriorly; antennae close to eye. Pronotum: with weak lateral carina; foretrochantin fused to propleuron. Metanotum: single sclerite in anterior half. Abdomen: segment 1 lateral hump with large spiny patch, without sclerites; gills absent.

Etymology. From the Latin *lata* meaning wide and *rima* meaning gap, and pertaining to the widely incised segment X and is feminine in gender.

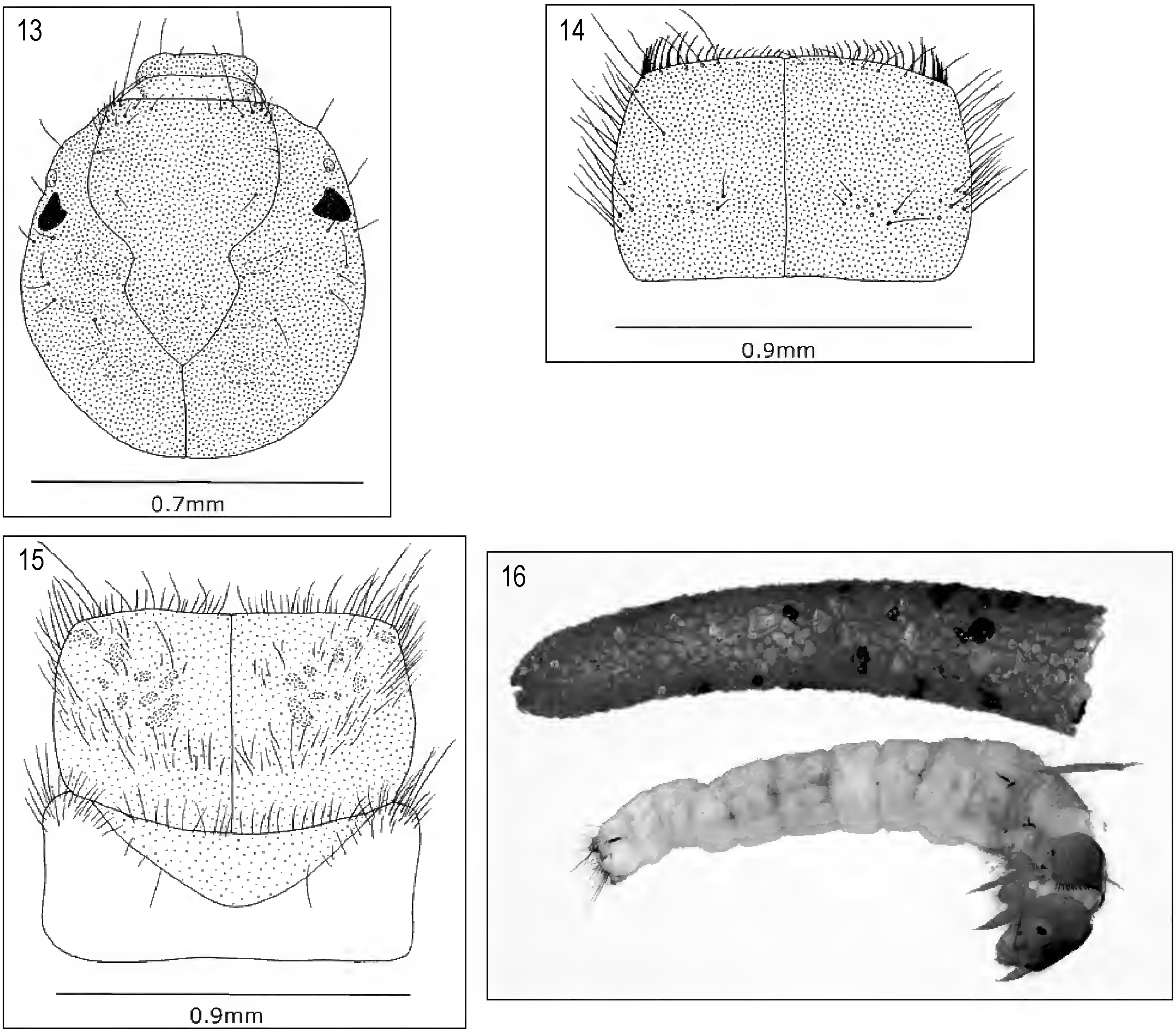
Material examined. Species included: *Latarima explicatala* sp nov. and *Latarima furcilla* (Neboiss, 1984a) comb. nov.



Figures 1–6. *Latarima explicatala*, Male: head, lateral (1); forewing (2); hind wing (3); genitalia (4–6), dorsal (4), ventral (5), lateral (6).



Figures 7–12. *Latarima explicatala*, Pupa: head, dorsal (7), ventral (8); anterior hook plate (9); posterior hook plate (10); terminal segment, dorsal (11), ventral (12).



Figures 13–16. *Latarima explicatala*, Larva: head, dorsal (13); pronotum, dorsal (14) mesonotum and metanotum, dorsal (15); larva and case, lateral (16).

Comments. Adults of *Latarima furcilla* have only been collected from a single stream on the road to Mt Buller, Victoria. Preliminary investigations suggest that a larva from the same site is a likely candidate for being associated with the adults of this species. However, this association has not yet been confirmed. The range of *L. explicatala* is much wider than that of *L. furcilla*. *Latarima explicatala* has been collected from the Yarra Ranges, Mount Baw Baw, Taggerty, Mount Buller, and at the Victorian-New South Wales border near Mt. Kosciuszko. These sites are all well forested and associated with mountains. Interestingly, one site where this *L. explicatala* has been collected from is less than 1km from the site at which *L. furcilla* is found, on Mt Buller.

Latarima explicatala sp nov.

Zoobank LSID. http://zoobank.org/urn:lsid:zoobank.org:act:2717E1DE-373A-45DD-8CCF-646CACB66499

Diagnosis. The adult males of *L. explicatala* sp nov. are distinguished from *L. furcilla* in that the hind wing does not possess a fold, abdominal segment X has more than one pair of spines apically, and the lateral projections on the phallus are more rounded and with crenulated dorsal margins.

Description. Adult male. Head (fig. 1): dark brown; one pair setal warts anterior to antennae, raised; antennae as long as body; antennal scape anterior apex extended, with anterior projection extending half way through pedicel, bulbous, densely setose on posterior half. Pronotum: Fore coxa with pale "Y" shape on anterior margin, mid coxa with setal wart, "Y" shaped on ventral surface; hind coxa with long setal wart dorso-ventrally on lateral margin; hind femur with pale patch 1/3 length from apex. Wings: Forewing (fig. 2): gold/brown, white areas on apical half; veins M_{3+4} and Cu_{1a} join at distal margin of thyridial cell. Hind wing (fig. 3): A_3 and A_2 terminate before basal quarter of wing; A_1 and Cu_2 almost fused, almost forming a fold. Genitalia (figs 4–6): Segment X divided into two elongate projections each with a large spine sub-apically on dorsal surface, a slender spine apically, and a slender spine sub-apically on ventral surface; preanal appendages about as long as segment X, slender, expanded shortly before rounded apex; inferior appendage in ventral view basally expanded, apices curved inward, broad in lateral view; phallus enlarged apically with a rounded flange on either side extending dorsally to near dorsal margin of segment X, flange with dorsal margin crenulated.

Pupa. Body: pale. Head: both mandibles similar in length, smooth, 2 setae on basal lateral margin; a seta near lateral margin anterior to each eye; two pairs of setae on anterior margin of frons; a pair of setae between antennae. Labrum apex with 3 dark setae either side on anterolateral margin; many setae on lateral margin near base. Antennal scape with 2 setae dorsally. Abdomen: lateral fringe present, thin; abdominal segments 3-6 each with 1 pair of anterior hookplates, hookplates bearing 2 hooks; 1 pair of posterior hookplates on segment 5, left hookplate with 2 hooks, right hookplate with 2–3 hooks. Terminal segment: with a row of 6 short setae transversely at around mid-length; ventrally with a pair of large lobes, around 9 setae between lobes and base of terminal process; terminal process fairly setose, distal overhang projecting radially.

Larva (fig. 10). Head (fig. 7): frontoclypeus lateral margins of anterior half curved outward, anterolateral margins with 7 erect setae; ridge along lateral margin of frontoclypeus extending to dorsal edge of eye; eye circled by un-pigmented area; antennae close to eyes. Pronotum (fig. 8): anterior margin with 2 distinct rows of setae, anterior row thicker, projecting medio-ventrally, short along medial margin but become longer towards lateral corner, posterior row hair like projecting upwards. Mesonotum (fig. 9): anterior margin with many hair like setae, with a band of setae from anterolateral corners to median approximately 1/3 from posterior margin. Metanotum (fig. 9): sclerite triangular; setae along anterior margin of sclerite. Abdomen: segment 1 with a pair of setae ventrally; abdominal prolegs with one accessory tooth, anal lateral sclerites densely setose. Case (fig. 10): composed of sand grains arranged into a curved cylinder, narrow membranous panels present laterally at posterior end.

Holotype. Male, Cement Ck nr Warburton, Victoria, 9 Jan 1657, A. Neboiss (TRI-22774).

Paratypes. 1 male collected with Holotype (TRI-25846).

Other Material Examined. *Victoria*: 1 male, Chalet Ck, east branch, Mount Buller, 20 December 1972 (TRI 26647) (illustrated). 1 male, Charlie Ck EPA site ABV, 20 Oct 2016, MS704. 1 larva, Talbot Ck, Thompson Valley Rd, 17 April 1985, D. Cartwright. 2 males, Cement Ck nr Warburton, 9 Jan 1657, A. Neboiss (TRI-25850). 1 male pupa, Cameron Ck site 3 surber 3, 13 Dec 1995, J. Barton. 1 male pupa, Whitehouse Ck, 13 Dec 1995, site 6 surber 4.

Etymology. From the Latin *explicatus* meaning unfolded and *ala* meaning wing, and pertaining to the hind wing which does not possess a fold.

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Four new species and a new genus of Antarctic sea cucumbers with taxonomic reviews of *Cladodactyla*, *Pseudocnus*, Paracucumidae and *Parathyonidium* (Echinodermata: Holothuroidea: Dendrochirotida)

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Abstract

O'Loughlin, P. M., Mackenzie M., Paulay, G. and VandenSpiegel, D. 2014. Four new species and a new genus of Antarctic sea cucumbers with taxonomic reviews of *Cladodactyla*, *Pseudocnus*, Paracucumidae and *Parathyonidium* (Echinodermata: Holothuroidea: Dendrochirotida). *Memoirs of Museum Victoria* 72: 31–61.

Four new species of Antarctic sea cucumbers are described, three with author O'Loughlin: *Crucella susannae*, *Euthyonidiella huwi*, *Laevocnus katrinae*; and *Laevocnus leachmani* with authors Davey and O'Loughlin. *Pseudocnus* Panning is reviewed, and Antarctic species separated into new genus *Laevocnus* O'Loughlin. We raise the three subspecies of *Pseudocnus dubiosus*, viz. *dubiosus* (Semper), *koellikeri* (Semper) and *leoninus* (Semper), to species status. We refer *Cucumaria croceoida* Vaney to the synonymy of *Cladodactyla crocea* (Lesson). We synonymize *Dendrelasia* O'Loughlin with *Cladodactyla* Brandt, and re-describe the reassigned *Cladodactyla sicinski* (O'Loughlin). This species broods in a dorsal marsupium. The diagnoses of genus *Parathyonidium* Heding and species *Parathyonidum incertum* Heding are reviewed. The type specimens for *Parathyonidium incertum* are listed. *Parathyonidium incertum* Heding is the only known Antarctic holothuroid that is a coelomic brooder. The Paracucumidae Pawson and Fell is reviewed. Phylogenetic trees are given for species in the genera *Cladodactyla*, *Heterocucumis*, *Staurocucumis*, *Laevocnus*, *Crucella* and *Paracucumis*. Tables are provided for the species of *Cladodactyla* and *Pseudocnus*. Keys are included for the species of genus *Laevocnus* and family Paracucumidae.

Keywords

Bransfield Strait; South Shetland Islands; Shag Rock; South Georgia; Cladolabidae; Cucumariidae; Paracucumidae; *Cladodactyla*; *Crucella*; *Dendrelasia*; *Euthyonidiella*; *Laevocnus*; *Paracucumis*; *Pseudocnus*; coelomic brood protection; new genus; new species; synonym.

Introduction

O'Loughlin *et al.* (2010) provided a comprehensive overview of the especially diverse Antarctic sea cucumber species with a list of 187 (including 51 until then not described). Three subsequent papers by O'Loughlin and VandenSpiegel (2010) on apodids, O'Loughlin and Whitfield (2010) on psolids, and O'Loughlin *et al.* (2013) on new species from Admiralty Bay in the South Shetland Islands have furthered our knowledge of Antarctic sea cucumbers. This fauna is predominantly endemic to south of the Antarctic Convergence. mtDNA sequence data are providing insight into additional cryptic species and synonymies, as evidenced in O'Loughlin *et al.* (2010). Recent Antarctic expeditions have continued to collect specimens of unknown species of sea cucumbers.

The BAS BIOPEARL I expedition in 2006, under the leadership of Katrin Linse on the RRS *James Clark Ross* (JR 144) to the Scotia Sea, sampled the shelf (200 and 500 m) and slope (1000 and 1500 m) of the Falkland Trough, Livingstone Island, Deception Island, Elephant Island, the South Orkney Islands, Southern Thule, South Georgia and Shag Rock. The

Linse *et al.* 2008 BIOPEARL II expedition (JR 179) sampled from 500 to 2500 m in the southern Bellingshausen and Amundsen Seas. The many sea cucumber specimens were sent on loan to Museum Victoria and were identified by Mark O'Loughlin, Melanie Mackenzie and Emily Whitfield. Two new Antarctic holothuroid species from these collections are described in this work.

An IPY–CAML expedition was conducted by NIWA from 29 January to 22 March 2008 on RV *Tangaroa* with expeditioner Niki Davey able to focus on sea cucumbers as part of her role. This voyage sampled in the Ross Sea and associated seamounts and abyssal plains. One of the new *Pseudocnus* Panning, 1949 species in this work (with authors Davey and O'Loughlin) was collected during this voyage and is included here because of our extensive review of genus *Pseudocnus*. A paper on other new sea cucumber species from this expedition and a comprehensive overview of Ross Sea holothuroids is in preparation (Davey *et al.*). A sea cucumber specimen was passed on to us from CEAMARC RSV *Aurora Australis* Voyage 3 off Adelie and George V Lands in 2007 / 2008. This single specimen is assigned to the same new *Pseudocnus* species found in the Ross Sea.

In March and April 2012 Susanne Lockhart (NOAA's US AMLR Program) participated in Expedition ANT–XXVIII/4 on RV *Polarstern* in the region of the Antarctic South Shetland Islands at shelf depths of about 50–500 m in support of the CCAMLR initiatives to detect Vulnerable Marine Ecosystems. The quantitative demersal finfish stock assessment survey provided Susanne with a rare opportunity for a quantitative assessment of Antarctic invertebrate abundance, distribution and biomass. Trawl net dimensions were measured *in situ* using a ScanMar net monitoring sonar system. A comprehensive invertebrate analysis from 64 successful trawls yielded 4,120 holothuroid specimens of which 217 lots with many hundreds of holothuroids were preserved and donated to Museum Victoria for determination. Up to 1425 sea cucumber specimens were taken per station indicating a density of up to 87,119 holothuroid specimens per square nautical mile. The subsequent identification of all specimens in Museum Victoria by Mark O'Loughlin, Melanie Mackenzie and Emily Whitfield revealed new species of which one is described here. Further papers will describe other new species and quantitative outcomes from this survey.

In O'Loughlin *et al.* (2013) new genus and species *Dendrelasia sicinski* O'Loughlin were described for a single specimen from Admiralty Bay in the South Shetland Islands. Amongst the many sea cucumbers collected by Susanne Lockhart around the South Shetland Islands (see above) there are many larger specimens that are conspecific with the smaller type specimen of *Dendrelasia sicinski* and that are also morphologically referable to *Cladodactyla* Brandt, 1835. We clarify these systematic issues.

O'Loughlin (1994) summarized knowledge on brood-protecting and fissiparous cucumariids, and O'Loughlin *et al.* (2009a) described additional examples. Reference was made in the recent paper to a species of brood-protecting *Parathyonidium* Heding, 1954 (in Heding and Panning, 1954) that is determined and discussed here as *Parathyonidium incertum* Heding, 1954 (in Heding and Panning, 1954).

We have reviewed the five relevant genera while describing new species of *Cladodactyla*, *Crucella* Gutt, 1990, *Euthyonidiella* Heding and Panning, 1954 and *Pseudocnus*, and report brood-protecting by *Parathyonidium incertum*. This systematic paper is based primarily on morphological observations, and shows generally good congruence and support from emerging genetic data. However, there are some conflicts between morphological indicators for generic referral and genetic data. We anticipate further genetic data and future comprehensive reviews of the relevant generic assignments, and await additional insight into morphology and genetic congruence before further generic re-assignments.

Methods

Scanning electron microscope (SEM) images were taken by Didier VandenSpiegel after clearing the ossicles of associated soft tissue in commercial bleach, air-drying, mounting on aluminium stubs, and coating with gold. Observations were made using a JEOL JSM-6480LV SEM. Measurements were made with Smile view software. Tissues were sent to Gustav Paulay (UF) for sequencing and the specimen locations, tissue codes, catalogue numbers and GenBank Accession numbers are recorded in Appendix 1. A 655 bp portion of the mitochondrial gene cytochrome oxidase subunit 1 (COI) was sequenced from selected specimens using the echinoderm barcoding primers COIceF (5'-ACTGCCCACGCCCTAGTAATGATATTTTT-TATGGTNATGCC-3') and COIceR (5'-TCGTGTGTC-TACGTCCATTCCTACTGTRAACATRTG-3') (Hoareau and Boissin 2010), as described in Michonneau and Paulay 2014. Note that these echinoderm specific primers amplify positions 242 to 898 in COI compared with positions 74 to 733 amplified by Folmer primers. Sequences have been submitted to GenBank (See appendix). COI sequences were aligned by eye and analyzed using Maximum Likelihood with 100 bootstrap replicates, implemented in MEGA (Tamura *et al.* 2013).

Photos of most specimens were taken in Museum Victoria by Melanie Mackenzie, in collaboration with Mark O'Loughlin, using a Nikon D300S digital camera with 60 mm Nikkor macro lens for large specimens, and a Leica DC500 high resolution digital camera system with Auto Montage software for small specimens. The photo of *Laevocnus leachmani* Davey and O'Loughlin sp. nov. was taken by Peter Marriot (NIWA) using a Nikon DX camera with a 60 mm macro lens. The photo of a live *in situ* brood-protecting specimen of *Cladodactyla crocea* (Lesson, 1830) in the Falkland Islands was provided by Paul Brickle (SMSG). Photos of live specimens of *Cladodactyla sicinski* (O'Loughlin, 2013) and *Crucella susannae* O'Loughlin sp. nov. were taken on the RV *Polarstern* and provided by Susanne Lockhart (NOAA's US AMLR). The photo of a live *in situ* specimen of *Cladodactyla sicinski* in Fildes Bay in the South Shetland Islands was taken by Dirk Schories (UACh).

Abbreviations

AAD	Australian Antarctic Division
AMLR	Antarctic Marine Living Resources

ANARE	Australian Antarctic Research Expedition
BAS	British Antarctic Survey
BENTART	Integrated study of the benthonic biodiversity of Bellingshausen Sea and Antarctic Peninsula (Spain)
BIOPEARL	BIOdiversity dynamics: Phylogeography, Evolution And Radiation of Life
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CEAMARC	Collaborative East Antarctic Marine Census
ICZN	The International Commission on Zoological Nomenclature, or the International Code of Zoological Nomenclature, as appropriate.
IPY–CAML	International Polar Year–Census of Antarctic Marine Life
MNCN	Museo Nacional de Ciencias Naturales (Spain)
MNHN	Muséum national d'Histoire naturelle (Paris)
MOLAF	Prefix code for tissues taken from specimens at NMV
MOLG	Prefix code for tissues taken from NIWA specimens in the University of Genoa
MOLN	Prefix code for tissues taken from NIWA specimens
MOLSI	Prefix code for tissues taken from Smithsonian Institution specimens
NDMQ	Prefix code for tissues taken by Niki Davey from Macquarie Island specimens
NHMUK	British Museum of Natural History (registration number prefix NHMUK)
NIWA	New Zealand National Institute of Water and Atmospheric Research Ltd. (est. 1992)
NMV	Museum Victoria (registration number prefix F)
NOAA	United States National Oceanic and Atmospheric Administration
SMSG	Shallow Marine Survey Group (Falkland Islands)
UACh	Universidad Austral de Chile
UF	Florida Museum of Natural History, University of Florida
USNM	United States National Museum of Natural History, Smithsonian Institution
ZMUC	Natural History Museum of Denmark (Zoology); Zoological Museum, University of Copenhagen

Numbers in brackets after registrations refer to numbers of specimens in lots.

Order **Dendrochirotida** Grube, 1840

Remarks. Smirnov (2012) established suborder Cucumariina for dendrochirotid families with the calcareous ring lacking segmented posterior prolongations. These included Cucumariidae Ludwig, 1894, Paracucumidae Pawson and Fell, 1965, and Thyonidiidae Heding and Panning, 1954 that was raised to family status by Smirnov (2012). No suborder was nominated for dendrochirotid families excluded from Cucumariina. These include Cladolabinae Heding and Panning, 1954 that was also raised to family status in Smirnov (2012). We do not nominate suborders of Dendrochirotida in this work.

Family **Cladolabidae** Heding and Panning, 1954 *sensu* Smirnov 2012

Diagnosis (after Smirnov 2012). Tentacles 15–20 arranged in 2 or 3 circles (10+5, 10+10, 10+5+5); tube feet arranged along radii or scattered over entire body; calcareous ring segments usually entire, high, not subdivided into pieces; radial plates with forked prolongations, medium length or short, usually entire or sometimes subdivided into a few very short pieces; sometimes short forked prolongations on inter-radial segments; ossicles tables with 2 pillars, disc with few perforations and sometimes reduced making tables rod-like, convex cross-like spined plates, and rosettes.

Remarks. Smirnov (2012) raised the subfamily Cladolabinae Heding and Panning, 1954 to family status, and offered his opinion that "quite possibly the family is polyphyletic".

Euthyonidiella Heding and Panning, 1954

Diagnosis (after Heding and Panning 1954). Tentacles 15–20; tube feet in radial or scattered arrangement; calcareous ring radial plates with paired long undivided posterior prolongations; ossicles tables with 2 pillars.

Type species. Euthyonidiella kyushuensis Heding and Panning, 1954 (type locality southern Japan) (by original designation)

Assigned species and type localities. Euthyonidiella ambigua (Heding, 1942) (Tanzania); *E. dentata* Cherbonnier, 1961 (Brazil); *E. destichada* (Deichmann, 1930) (Caribbean Sea); *E. dubia* Cherbonnier, 1958 (Sierra Leone); *E. huwi* O'Loughlin sp. nov. (below; Shag Rock); *E. kyushuensis* Heding and Panning, 1954 (Kyushu); *E. trita* (Sluiter, 1910) (Caribbean Sea); *E. tungshanensis* (Yang, 1937) (Fujian Sea); *E. zacae* (Deichmann, 1938) (Galapagos).

Remarks. The species assigned to *Euthyonidiella* are quite similar morphologically with the exception of *Phyllophorus tungshanensis* Yang, 1937 (assigned to *Euthyonidiella* by Liao and Clark 1995), and *Euthyonidiella dubia* Cherbonnier, 1958. We question these two assignments. A specimen from NW Australia collected at 184–187 m depth (NMV F149748; UF tissue sequence code MOL AF 408) morphologically closely resembles both *Euthyonidiella kyushuensis* from south Japan and *Euthyonidiella ambigua* from east Africa. This specimen is provisionally determined as *Euthyonidiella kyushuensis*.

Euthyonidiella huwi O'Loughlin sp. nov.

Zoobank LSID. http://zoobank.org:act:8DD8AA4E-E46C-4FDE-8A14-F796CA2B0427

Figure 1

Material examined. Holotype. Western Antarctica, Shag Rock, 53°38'S 40°54'W, 206 m, BAS BIOPEARL I stn SR–EBS–4, 11 Apr 2006, NMV F168650 (UF tissue sequence code MOL AF 816).

Paratypes. Type locality and date, NMV F189889 (3 small juveniles); NHMUK 2010.137–138 (2).

Other material (not *Euthyonidiella huwi*). *Euthyonidiella kyushuensis* Heding and Panning, 1954. NW Australia, 17°29'S 120°28'E, 184–187 m, RV *Southern Surveyor*, SS05/2007 stn 91, 20 Jun 2007, NMV F149748 (1) (UF tissue sequence code MOL AF 408).

Description. Body cylindrical, slightly pentagonal in transverse section, rounded anterior and posterior, up to 7 mm long (tentacles deeply withdrawn), up to 2 mm diameter; thin calcareous body wall with surface bristle of table spires; 20 dendritic tentacles, 5 pairs large, 5 pairs very small, latter probably in slightly inner ring; tube feet in irregular single to double radial series, some spread inter-radially; calcareous ring high, not segmented; anterior end of radial plates with deep division at muscle attachment and with lateral notch, posterior prolongations short, forked, not segmented (ring of 2 mm long paratype specimen lacking posterior prolongations); inter-radial plates with anterior taper, blunt posterior, lacking posterior prolongations; short stone canal with bean-shaped madreporite free in coelom; single tubular polian vesicle.

Body wall with abundant irregular tables: discs round to slightly oval, margins lobed around perforations, 2 large central perforations, frequently 6 (up to 14) additional perforations, perforations most numerous in smallest specimens, discs predominantly 70 μm long, up to 90 μm long; spires with 2 pillars up to 40 μm long, spinous distally, sometimes with connecting bridges distally, distal bridges sometimes with spines on mid-bridge. Tentacles with irregular thick elongate perforated plates, up to 88 μm long. Peri-anal body wall with abundant tables and internal thick knotted scale-like ossicles.

Colour (preserved). White.

COI DNA barcode of holotype: AATAATGATCGGGGGGTTTGGGAACTGATTAATCCCACTAATGATTGGAGCACCAGACATGGCTTTTCCCCGAATGAAAAAAATGAGATTCTGACTAATCCCCCCCTCATTTATTTTACTCTTAGCTTCAGCAAGAGTAGAAAGAGGGGCAGGAACTGGTTGGACGGTATACCCCCCTCTTTCAAGAAAAATAGCTCACGCAGGAGGCTCAGTTGACTTAGCAATATTTTCCCTTCACCTAGCGGGAGCCTCATCAATTCTAGCTTCTATAAAATTTATAACTACAATAATAAAAATGCGAACCCCAGGGGTAAGTTTTGACCGACTATCCCTATTTGTGTGGTCAGTATTTATTACAGCCTTTCTTCTACTTCTGAGACTCCCAGTATTAGCCGGGGCTATAACCATGTTACTAACTGATCGTAATATTAATACAACGTTTTTTGACCCTGCGGGAGGGGGTGATCCCATATTATTTCAACATCTATTCTGATTCTTTGGTCATCCAGAAGTGTACATTCTAATCTTACCAGGCTTCGGTATGATTTCCCATGTCATTGCTCATTATAGAGGAAAGCAAGAACCCTTCGGATATTTAGGTATGGTCTATGCAATGGTAGCCATAGGTATTTTAGGATTTTTAGTTTGAGCCCAC

Distribution. Western Antarctica, Shag Rock, 54°S 41°W, 206 m.

Etymology. Named for Huw Griffiths (British Antarctic Survey), in appreciation of his role in the BAS BIOPEARL expeditions, his contribution to collecting the specimens studied here, and with gratitude for his gracious collaboration in Antarctic holothuroid research.

Remarks. Euthyonidiella huwi O'Loughlin sp. nov. is distinguished from the other species of *Euthyonidiella* by a combination of: predominantly radial occurrence of tube feet; table discs that sometimes have more than eight perforations; relatively short posterior prolongations on the radial plates of the calcareous ring. The provisionally determined specimen of *Euthyonidiella kyushuensis* from NW Australia and *Euthyonidiella huwi* from Antarctica are sister taxa among 19 sequenced sclerodactylids *sensu lato* based on CO1 sequences, although they are quite divergent from each other (K2P pairwise distance = 0.20). We observed that the calcareous ring of a 2 mm long juvenile of *Euthyonidiella huwi* lacked posterior prolongations. We recognize that the relatively short posterior prolongations in the 7 mm long holotype may represent ontogenetic change, as may the sometimes more numerous perforations in the table discs and predominantly ambulacral occurrence of the tube feet. We acknowledge the unsatisfactory element in describing a new species from a few small specimens that may represent developmental stages, but we judge that it is important to establish the occurrence of genus *Euthyonidiella* Heding and Panning in Antarctica.

Family **Cucumariidae** Ludwig, 1894

Subfamily **Cucumariinae** Ludwig, 1894 *sensu* Panning 1949

Diagnosis. Ten dendritic tentacles; calcareous ring lacking segmented posterior prolongations; ossicles in the body wall perforated plates, sometimes rods, never cups or tables.

Cladodactyla Brandt, 1835

= *Dendrelasia* O'Loughlin (in O'Loughlin *et al.*, 2013): 69–70 (new synonymy)

Table 1; figure 2

Diagnosis (sensu stricto – see Remarks). Ten equal tentacles; calcareous ring calcified and evident in small specimens but de-calcified and no longer evident in larger specimens; tube feet restricted to radii; dorso-lateral radial body wall thick, soft, "spongy"; external dorsal marsupium created by elongate indentation / invagination between dorso-lateral radii, radial edges may close over a protective chamber, anterior mid-dorsal gonoduct opening in marsupium; hermaphroditic; tube feet on bivium smaller and more numerous than on trivium; respiratory trees arise from 3–4 basal sources, each with dendritic branches; mid-body wall ossicles absent in larger specimens; peri-anal ossicles include prominently spinous, single-layered, perforated plates.

Table 1. Species currently assigned to *Cladodactyla*, occurrence, and contrasting morphological characters.

Species	**Occurrence**	**Dorsal marsupium**	**Tentacles**	**Calcareous ring**	**Body wall ossicles**
C. *brunspicula* Thandar, 2008	South Africa	Lacking	10 equal; with rosettes	calcified	plates with small to filled perforations
C. *crocea* (Lesson, 1830)	Falkland Islands	Present	10 equal, lacking rosettes	not calcified in larger specimens	lacking in larger specimens
C. *monodi* Cherbonnier, 1950	Cameroon	Lacking	2 small ventral, lacking rosettes	calcified	perforated plates
C. *senegalensis* Panning, 1940	Senegal	Lacking	2 small ventral; lacking rosettes	calcified	perforated plates
C. *sicinski* (O'Loughlin, 2013)	South Shetland Islands	Present	10 equal, lacking rosettes	not calcified in larger specimens	lacking in larger specimens

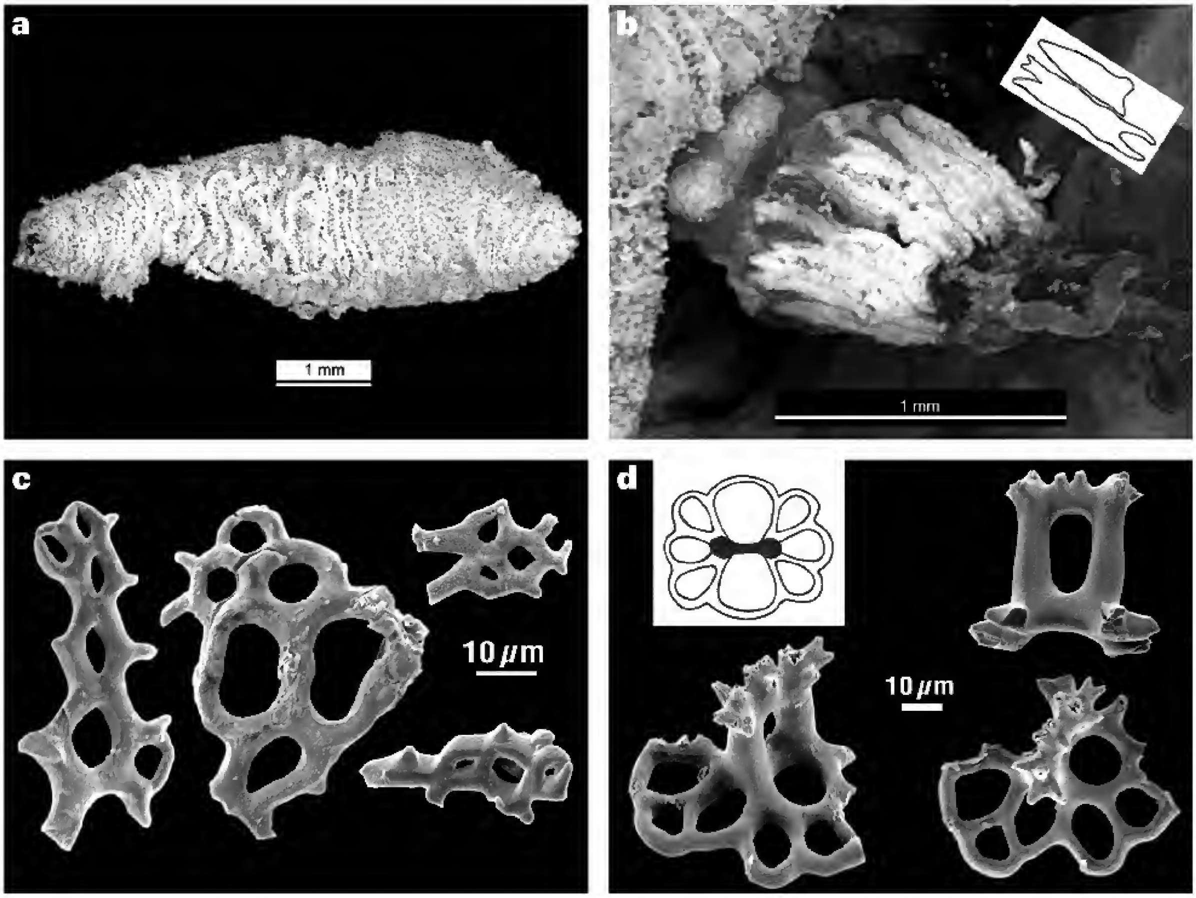

Figure 1. Holotype of *Euthyonidiella huwi* O'Loughlin sp. nov. (NMV F168650). a, preserved holotype; b, photo of calcareous ring, single polian vesicle (lower right), madreporite and stone canal (upper right) (insert: drawing of radial (bottom) and inter-radial (top) plates of the calcareous ring); c, SEM images of ossicles from the tentacles; d, SEM images of table ossicles from mid-body wall (insert: drawing of one common form of variable table discs).

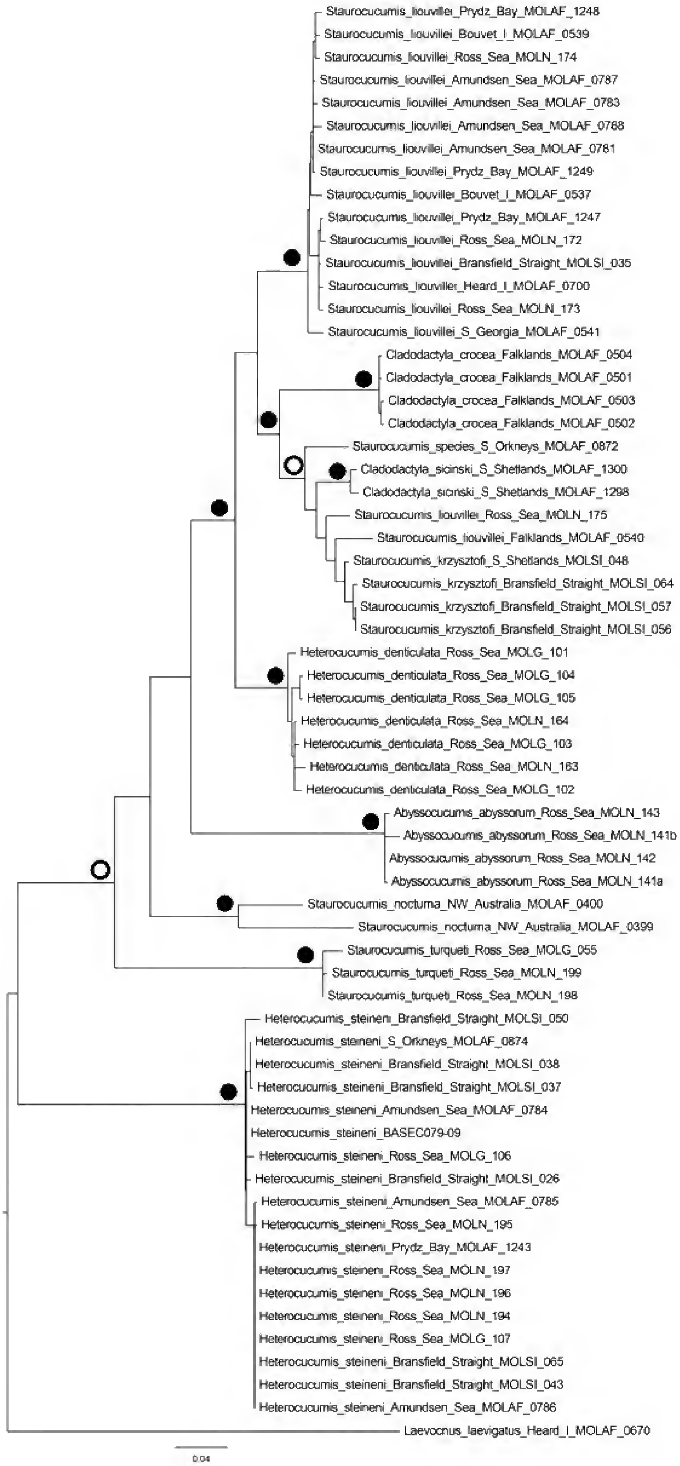

Figure 2. Maximum likelihood tree for *Cladodactyla–Heterocucumis–Staurocucumis* clade, based on COI sequences, T92+G+I model, 100 bootstrap replicates, *Laevocnus laevigatus* as outgroup. Filled circles >0.95 bootstrap support; hollow circles >0.70 bootstrap support.

Type species. Holothuria crocea Lesson, 1830 (type locality Falkland Islands (Malvinas)) (by subsequent designation (Panning 1940: 170))

Remarks. The availability of numerous larger specimens of *"Dendrelasia" sicinski* from the South Shetland Islands has enabled us to judge that *Dendrelasia* is a junior synonym of *Cladodactyla* (see below). We formalize the synonymy here. We base our *sensu stricto* diagnosis of *Cladodactyla* on the two species that we consider to be *Cladodactyla* in confidence: *C. crocea* and *C. sicinski.* The differences (Table 1) in the presence or absence of a dorsal external marsupium, tentacle arrangement, calcification in the calcareous ring, and ossicle forms, and the broad geographic distribution of the other included species, lead us to suspect that *Cladodactyla* as currently circumscribed may not be monophyletic.

COI sequence data from several hundred dendrochirotids (Michonneau *et al.* in prep.) recovers these two species of *Cladodactyla* in a clade with *Staurocucumis* (including *Abyssocucumis*, considered generically distinct by some (Hansen 1988, O'Loughlin 2002) but not others (Massin & Hendrickx 2011)) and *Heterocucumis*, with modest support. An analysis of this clade (Fig. 2), including samples of the type species of all four genera: *Cladodactyla crocea, Staurocucumis liouvillei, Abyssocucumis abyssorum, Heterocucumis steineni*, fails to recover these genera as monophyletic, and includes a subclade with 96% bootstrap support that has species of *Staurocucumis, Heterocucumis,* and *Cladodactyla* intermixed. Revising the generic limits of this lineage is beyond the scope of this paper. We note however that *Cladodactyla*, as the senior generic name in this assemblage, is clearly appropriate for *C. crocea* and *C. sicinski.*

Cladodactyla crocea (Lesson, 1830)

Figures 2, 3, 4; table 1

Holothuria (Cucumaria) crocea Lesson, 1830: 153–154, pl. fig. 1.

Cladodactyla crocea.—Brandt, 1835: 43.—Wyville Thomson, 1878: 57–61, fig. 1.—Panning, 1957: 27–29, figs 10–13.

Cucumaria crocea.—Théel, 1886: 58–61, pl. 3 fig. 5, pl. 12 figs 1, 2 (see Remarks).—Ludwig, 1898: 15–24, pl. 1 figs 6–13.—Vaney, 1908a: 296.—1908b: 23–24.—Ekman, 1925: 75–81, figs 15, 16.

Cucumaria croceoida Vaney, 1908a: 299.—1908b: 31, pl. 5 figs 64–66.

Cucumaria crocea var. *croceoides.*—Ekman, 1925: 81–85, fig. 17.

Material examined. South-west Atlantic Ocean, Falkland Islands, *Discovery Expedition*, RRS *William Scoresby*, WS stn 231, 50°10'S 58°42'W, 159–167 m, 4 Jul 1928, NHMUK 2013.1 (1); W of Falkland Is, WS stn 867, 51°10'S 64°16'W, 148–150 m, 30 Mar 1932, NHMUK 2013.2 (1); WS stn 869, 52°16'S 64°14'W, 187 m, 31 Mar 1932, NHMUK 2013.3 (1); Falkland Is, US AMLR 2004 *Icefish* stn 17–OT20, 52°22'S 58°52'W, 78 m, S. Lockhart, 31 May 2004, NMV F105017 (4) (UF tissue sequence codes MOL AF 501, 502); *Icefish* stn 18–OT14, 52°08'S 58°05'W, 93 m, S. Lockhart, 28 May 2004, NMV F106967 (3) (UF tissue sequence code MOL AF 504); *Icefish* stn 21–OT16, 52°43'S 59°97'W, 120 m, S. Lockhart, 30 May 2004, NMV F105002 (3) (UF tissue sequence code MOL AF 503); Burdwood Bank, *Icefish* stn 5–BT4, 54°47'S 59°18'W, 303 m, S. Lockhart, 21 May 2004, NMV F160031 (1) (UF tissue code MOL AF542); Falkland Is, *Challenger* stn 315, 51°40'S 57°50'W, 9–22 m, 26–28 Jan 1876, USNM E10614 (2); Tierra del Fuego, Cape Penas, *Eltanin* stn 966, 53°40'S 66°20'W, 81 m, 10 Feb 1964, USNM E33519 (46).

Description. Body cylindrical, rounded orally and anally, up to 100 mm long 30 mm diameter (live, in Wyville Thompson 1878; 47 mm long preserved, in Ekman 1925); body wall soft, leathery, dorso-lateral radial body wall thick, soft, "puffy"; dorsal marsupium created by elongate indentation / invagination between dorsal radii; 10 equal tentacles; ring not calcified in larger specimens; tube feet restricted to radii in paired zig-zag rows, smaller and more numerous in dorso-lateral than in ventral radii, outer ventro-lateral rows of tube feet fewer and more spaced, dorsal tube feet absent in small specimens, often withdrawn into pits in preserved specimens; dorso-lateral radial tube feet do not cross inter-radius at anterior and posterior ends of marsupium; single polian vesicle; paired, unbranched tufts of hermaphroditic gonad tubules, genital papilla anterior mid-dorsal in marsupium; 2 respiratory trees, each divided basally into 2 sub-equal or unequal dendritic branches creating 4 trees, extending about two-thirds length of coelom.

Mid-body wall ossicles absent from largest specimens; in smaller specimens ossicles absent from marsupium wall but mid-lateral body wall with thick rods and spinous plates, rods frequently with single to numerous distal perforations, frequently with distal and lateral spines and branches, plates irregularly oval to round, with two larger central perforations, surface and margin with sharp spines, rods and plates intergrade, up to 296 μm long. Dorsal tube foot endplates up to 280 μm diameter, endplate support ossicles curved, distally perforate, spinous rods up to 136 μm long. Ventral tube feet endplates with irregular perforations, diameter about 360 μm, endplate support rods as in body wall but curved, about 168 μm long. Tentacle ossicles irregular thick rods with distal and sometimes lateral perforated extensions, with marginal denticulations around perforated parts, up to 272 μm long. Introvert lacking ossicles. Peri-anal body wall ossicles spinous rods and plates as in body wall, up to 176 μm long, and some larger oval plates with spinous margin, plates up to 240 μm long, no spinous crosses detected.

Colour. Live: body orange yellow, tentacles white. Preserved: body pale brown to grey to cream to pink with brown spots variably evident.

Distribution. South-west Atlantic Ocean, Falkland Islands (Malvinas), Burdwood Bank, Tierra del Fuego, 0–303 m.

Remarks. The synonymy above is selective and does not include the comprehensive list of early references provided by Ludwig 1898. Théel (1886) provided good illustrations (pl. 3 fig. 5) of the ossicles of *Cladodactyla crocea* but reported them as *Cucumaria laevigata*, and wrongly reported two small ventral tentacles for *Cladodactyla crocea*. Lampert (1886) was confused in his discussion of *Cucumaria crocea* and illustrated ossicles of *Pentactella laevigata* Verrill, 1876. *Cladodactyla crocea* is distinguished from the other *Cladodactyla* species by the combination of: presence of a

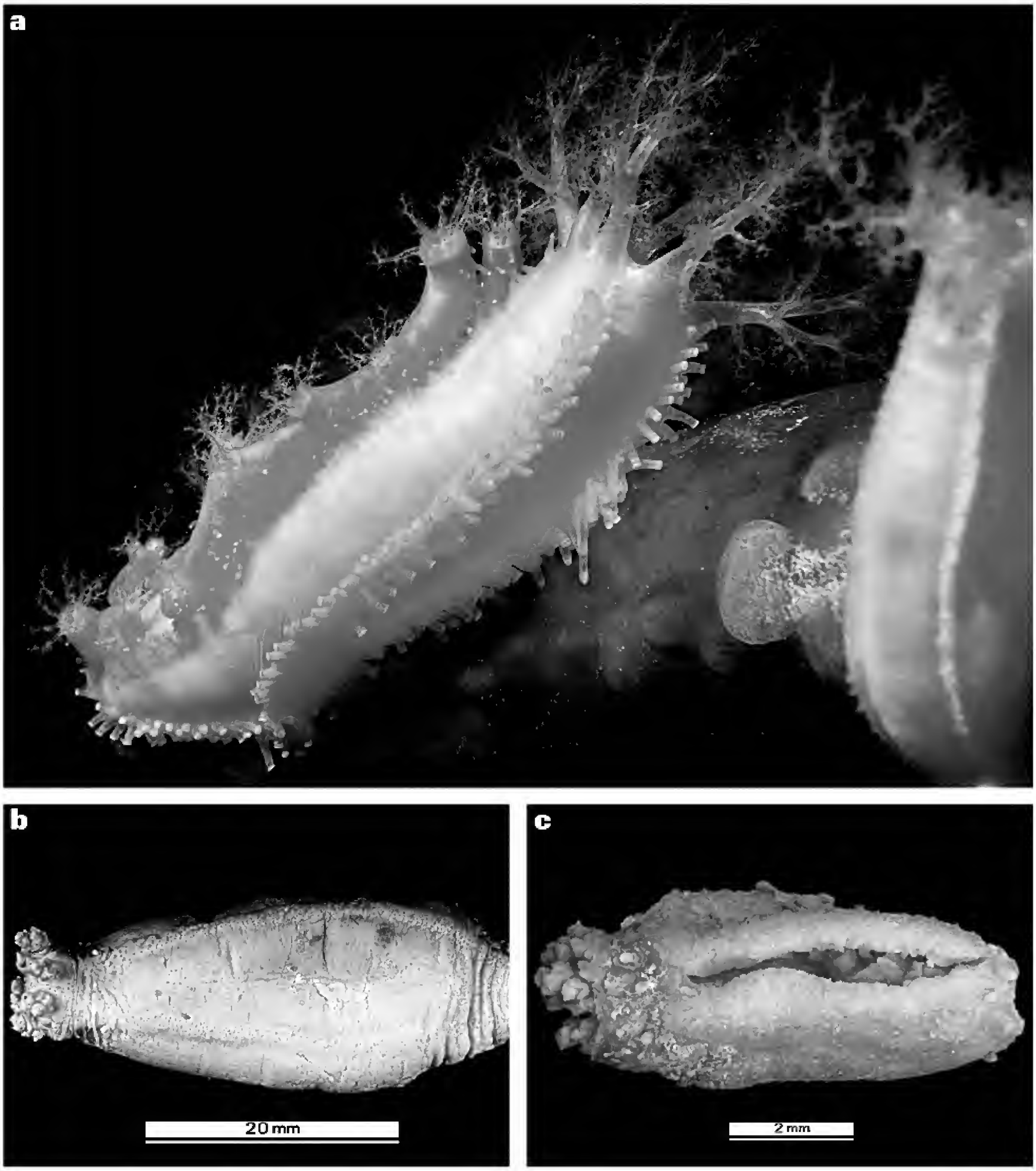

Figure 3. *Cladodactyla crocea* (Lesson, 1830). a, *in situ* photo of lateral view of live specimen with juveniles on the dorsal marsupium (Falkland Islands; photo by SMSG); b, dorsal view of 35 mm long preserved specimen showing thickened marsupial dorsal radial rims with numerous very small tube feet (NMV F105017); c, dorsal view of 8 mm long preserved specimen showing invaginated marsupium with enclosed embryos (NMV F160031).

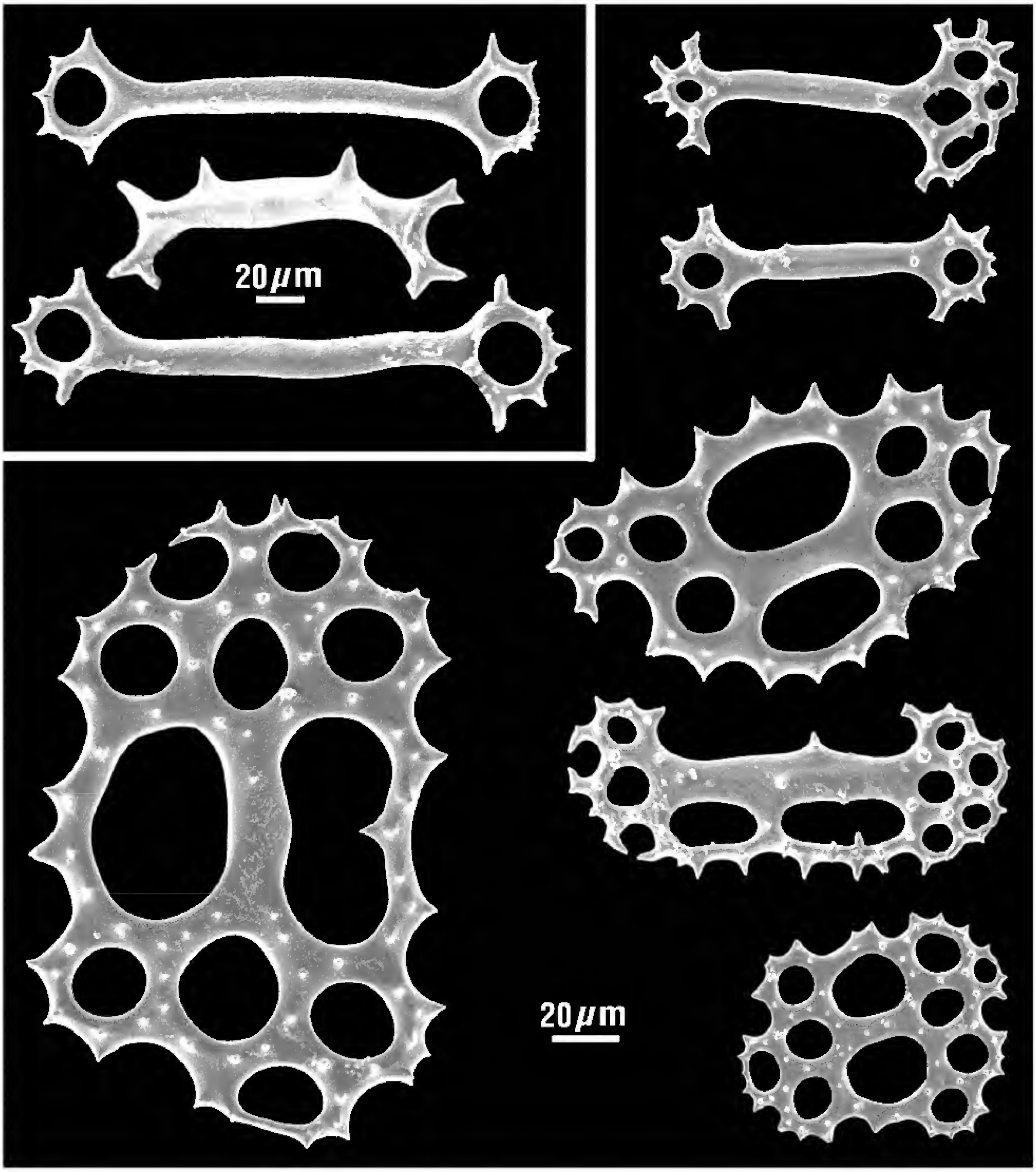

Figure 4. SEM images of ossicles from specimens of *Cladodactyla crocea* (Lesson, 1830). Main figure with spinous rods and plates from the dorso-lateral body wall of a 15 mm long specimen (NMV F105002); top left box with spinous rods from the lateral body wall of a 28 mm long specimen (NMV F106967).

dorsal external marsupium; dorso-lateral radial tube feet series not continuous anteriorly and posteriorly across the dorsal inter-radius to create a complete border to the marsupium; 10 equal tentacles; tentacle ossicles rods not plates; absence of introvert ossicles; presence of tube feet support rod ossicles; lack of spinous crosses in the peri-anal body wall.

Ekman (1925) found variations in body wall ossicle form, and in the presence or absence of ossicles, in specimens that he judged to be *Cucumaria crocea* and *Cucumaria croceoida* Vaney, 1908. Ekman could distinguish two groups, but acknowledged that there was an overlap, and thus relegated Vaney's species to a variety of Lesson's. We observed similar variations among specimens of *Cladodactyla crocea*, and thus judge that the variety *croceoides* should not have formal status and refer it to the synonymy of *Cladodactyla crocea*.

Cladodactyla sicinski (O'Loughlin, in O'Loughlin et al., 2013)

Dendrelasia sicinski O'Loughlin (in O'Loughlin *et al.*), 2013: 70–73, figs 1–3.

Figures 2, 5, 6, 7, 8; table 1

Material examined. Holotype of *Dendrelasia sicinski.* Western Antarctica, South Shetland Islands, King George Is, Admiralty Bay, 200–250 m, P. Presler and J. Siciński, 1 Mar 1980, NMV F189855.

Other material. Western Antarctica, Elephant I., 61.26°S 54.90°W, 158 m, RV *Polarstern* ANT–XXVIII/4 stn 191, 18 Mar 2012, NMV F193767 (1); 61.20°S 54.90°W, 63 m, *Polarstern* ANT–XXVIII/4 stn 190, 18 Mar 2012, NMV F193770 (1); 61.34°S 55.49°W, 155 m, stn 195, 19 Mar 2012, NMV F193768 (1); 60.88°S 55.45°W, 243 m, stn 208, 21 Mar 2012, NMV F193769 (1); 60.98°S 55.69°W, 92 m, stn 229, 24 Mar 2012, NMV F193771 (5); 61.14°S 55.69°W, 78 m, stn 230, 24 Mar 2012, NMV F193766 (1) (UF tissue sequence code MOL AF 1298); South Shetland Is, 62.33°S 60.49°W, 119 m, stn 253, 29 Mar 2012, NMV F193772 (3) (UF tissue sequence code MOL AF 1300).

Description (emended). Body fusiform, cylindrical in mid-body, tapers roundly at both ends; preserved body up to 70 mm long, 28 mm diameter; body wall thin to thick, soft, leathery; 10 equal dendritic tentacles; calcareous ring evident and calcified in small specimens, but becoming decalcified in 15 mm long specimen, and thus no longer evident in larger specimens; dorso-lateral radial body wall thick, soft; tube feet on dorso-lateral radii in paired close zig-zag rows on each radius, series extended across dorsal inter-radius anteriorly and posteriorly to border an external brood-protecting marsupium, dorso-lateral radial tube feet smaller and more numerous than ventral tube feet, tube feet on dorso-lateral radii may be withdrawn into pits; tube feet on trivium larger and fewer than on bivium, ventral radial series in paired zig-zag rows, fewer in outer rows of ventro-lateral series; shallow median groove in flat longitudinal muscles; single polian vesicle; paired, un-branched tufts of hermaphroditic gonad tubules, gonoduct opens at pore in mid-anterior marsupium; lacking male genital papilla; respiratory trees arise from 3–4 basal sources, each with dendritic branches, extending about half length of coelom.

Larger specimens lack mid-dorsal and mid-ventral body wall ossicles; 15 mm long specimen with prominently spinous rod, X-shape, Y-shape and branched forms up to 136 μm long. Tentacle ossicles predominantly perforated plates, some rods; plates thin, irregular, with denticulate margins, sometimes with fine surface spines, and larger central perforations; rods frequently with distal and lateral perforate developments and denticulate margin; plates and rods both up to 200 μm long. Introvert lacking ossicles. Dorsal tube feet endplates up to 480 μm diameter; tube foot support plates oval to sub-rectangular to pear-shaped to half-moon shaped, 2 large perforations centrally, margin denticulate to spinous to smooth, some with fine surface spines, up to 160 μm long. Ventral tube foot endplates up to 960 μm diameter, outer rim of endplate comprises fused irregular branched rods, not perforations, central perforations slightly larger than outer ones, tube foot support plates oval with surface and marginal spinelets, surface sometimes smooth, 4 large central perforations, 2 largest perforations adjacent, 2 smaller distal perforations, up to 208 μm long. Peri-anal body wall with plates, crosses, rods; single-layered perforated anal plates up to 320 μm wide, plates irregularly oval with marginal spines or denticulations, with or lacking surface spines, frequently 4 large central perforations in cross formation as described above; amongst the body wall ossicles small clusters of irregular distally spinous crosses of variable rod thickness, arms frequently bifid, sometimes with branches joined to create 8 perforations and slightly concave sub-rectangular plates, crosses up to 112 μm long; rare spinous or denticulate rods, with or without distal perforations, up to 96 μm long; all three peri-anal ossicle forms inter-grade.

Colour. Live: body and tentacles pale yellow, oral disc red. Preserved: body variably off-white to pale grey-brown; tentacle discs with paired brown markings anterior to each tentacle, sometimes fine brown spotting on the oral disc.

Distribution. Western Antarctica, South Shetland Is, Elephant I., 63–250 m.

Remarks. The SEM images of peri-anal ossicles in the recent Susanne Lockhart collection of larger specimens of a species of *Cladodactyla* from the South Shetland Islands are distinctive. They are identical in general shape and form with the peri-anal ossicles from a smaller specimen from Admiralty Bay in the South Shetland Islands illustrated in O'Loughlin *et al.* 2013 for the new genus and species *Dendrelasia sicinski* O'Loughlin, 2013. The small specimen from Admiralty Bay is morphologically conspecific with the larger specimens of the recent Lockhart collection. *Dendrelasia* is a junior synonym of *Cladodactyla*.

In specimens of *Cladodactyla sicinski* there is a distinct dorsal external marsupium. Indentations present in the soft inter-radial dorsal body wall within the marsupium suggest a prior presence of embryos or juveniles. *Cladodactyla sicinski* is distinguished from the other *Cladodactyla* species by the combination of: presence of a dorsal external marsupium; dorso-lateral radial tube feet series continuous anteriorly and posteriorly across the dorsal inter-radius to create a complete border to the marsupium; 10 equal tentacles; tentacle ossicles predominantly plates; absence of ossicles in the introvert; presence of tube feet support plate ossicles; presence of spinous crosses in the peri-anal body wall.

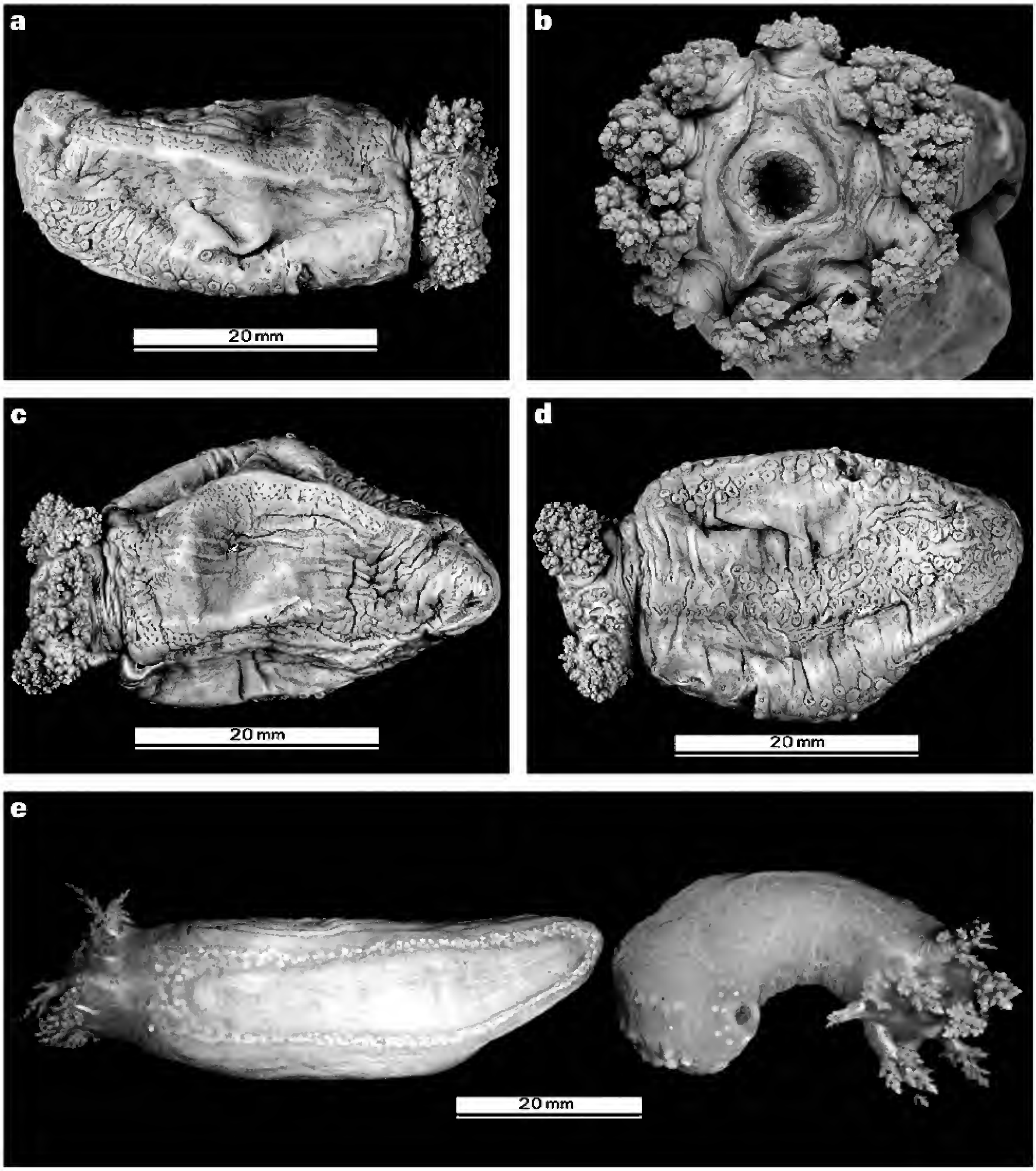

Figure 5. *Cladodactyla sicinski* (O'Loughlin, 2013) (preserved specimen, NMV F193767). a, right lateral view; b, tentacles; c, dorsal view (marsupium surface); d, ventral view; e, photos of two live specimens (South Shetland Islands; NMV F193772; photos by Susanne Lockhart).

Pseudocnus Panning, 1949

Figure 9; table 2

Pseudocnus Panning, 1949: 422–425.—Panning, 1951: 73–80.—Panning, 1962: 57–80.—Thandar, 1987: 288–289.—Lambert, 1998: 474–476.—O'Loughlin and Alcock, 2000: 4.

Diagnosis (sensu stricto – see Remarks). Ten equal dendritic tentacles; tube feet in radial series, additional smaller tube feet scattered in inter-radii; ossicles in body wall of two forms, knobbed buttons typically regular in form with four perforations and lacking marginal spines at one end, and single-layered knobbed plates with spines at one tapered end; tentacles with perforated plates, rod-like plates and rosettes.

Type species. Cucumaria koellikeri Semper, 1868 (type locality Mediterranean Sea) (original designation by Panning 1949). Panning (1962) proposed an invalid re-designation of *Cucumaria dubiosa* Semper, 1868 as type.

Remarks. Panning (1949) designated *Cucumaria koellikeri* Semper, 1868 (type locality Mediterranean Sea) as type species of his new genus *Pseudocnus*. Subsequently Panning (1962) came to believe that his re-description (Panning 1949) of *Cucumaria dubiosa* Semper, 1868, as another species of *Pseudocnus*, was based on a specimen also belonging to *C. koellikeri*. This was rectified in Panning (1962) when synonymies and full descriptions of both *P. dubiosus* and *P. koellikeri* were given and Panning proposed, invalidly, to change the type of *Pseudocnus* to *Cucumaria dubiosa* (type locality Peru). The diagnostic description in Panning (1949) of

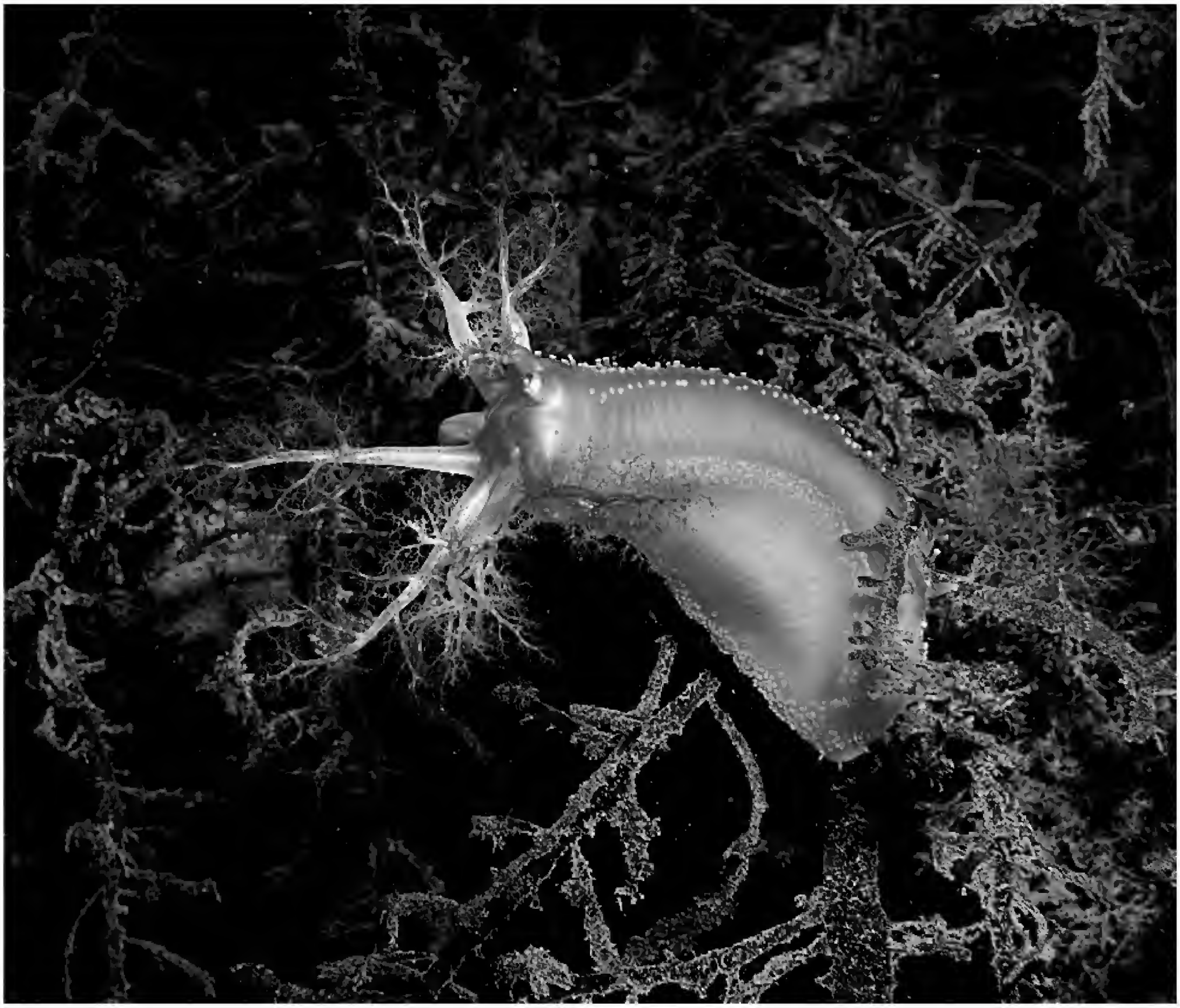

Figure 6. Photo of a live specimen of *Cladodactyla sicinski* (O'Loughlin, 2013) *in situ* in Fildes Bay on King George Island in the South Shetland Islands (photo taken by Dirk Schories (UACh) and used with permission).

Pseudocnus koellikeri (Semper, 1868) was accurate. A significant diagnostic difference between these two species is that *Pseudocnus dubiosus* has eight large and two small tentacles, while *Pseudocnus koellikeri* has 10 equal tentacles. Our *sensu stricto* diagnosis of *Pseudocnus* is based on the descriptions of the type species *Cucumaria koellikeri* by Koehler (1921, 1927) and Panning (1949, 1962).

Panning (1949) described, then revised (1962), *Pseudocnus*. In his revision he considered five taxa to be sub-species, all within his "*dubiosus* group": *Pseudocnus dubiosus africanus* (Britten, 1910) (junior synonym of *Pseudocnella insolens* (Théel, 1886) by Thandar 1987); *Pseudocnus dubiosus dubiosus* (Semper, 1868); *Pseudocnus dubiosus jaegeri* (Lampert, 1885) (junior synonym of *Pseudocnella sykion* (Lampert, 1885) by Thandar 1987); *Pseudocnus dubiosus koellikeri* (Semper, 1868); *Pseudocnus dubiosus leoninus* (Semper, 1867). On the basis of significant morphological differences (see Table 2 and new genus below) we raise three of these sub-species to species status: *P. koellikeri*, *P. dubiosus* (s.s.), and *P. leoninus*. As noted above Thandar (1987) transferred the remaining two to *Pseudocnella* Thandar, 1987.

Deichmann 1941 stated that *Cucumaria salmini* Ludwig, 1875 (type locality: Sulawesi, Indonesia) was probably a junior synonym of *Cucumaria leonina* Semper, 1867 (assumed type locality: "Singapore"), because of their similarity and presumed proximity of occurrence, rejecting Ekman's 1925 conclusion that the type locality for *Cucumaria leonina* was in error. Panning 1962 however, reaffirmed Ekman's 1925 conclusion, noting that the type was preserved in "rum from Singapore", and considered the type locality for *C. leonina* to be around the Falkland Islands (Malvinas). Ludwig (1875) likened the ossicles of his *C. salmini* to Semper's 1868 *C. dubiosa*, and referred to the illustration of a distally spinous plate and knobbed button in Semper's figures. *C. leonina* also has this ossicle combination. While we have not restudied the type of *C. salmini* we consider it unlikely that this tropical Pacific species would be conspecific with a sub-antarctic South American species. We thus raise *Pseudocnus salmini*

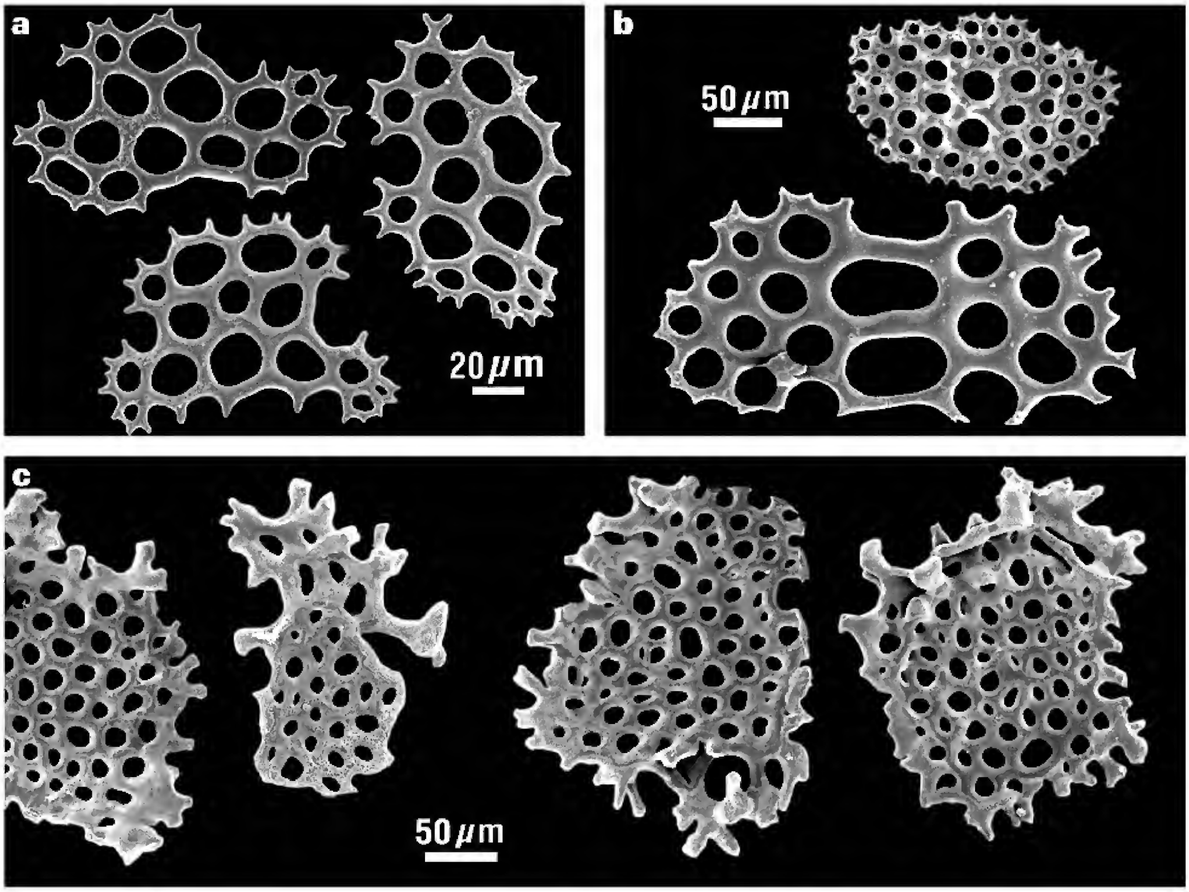

Figure 7. SEM images of ossicles from specimen of *Cladodactyla sicinski* (O'Loughlin, 2013) (NMV F193767). a, tentacle ossicles; b, ventral tube foot ossicles with presumed to be residual body wall plate (top) and tube foot support plate (bottom); c, ventral tube foot endplate fragments with rim of fused outer marginal support rods.

out of synonymy (by Deichmann 1941) with *Pseudocnus leoninus*. We provisionally refer *P. leoninus* to the new genus (below) on the bases of supportive genetic data and sub-Antarctic occurrence. We do not refer *P. salmini* to the new genus for three reasons: Ludwig (1875) likened the ossicles to those of *C. dubiosa*; tropical occurrence; absence of any indicative genetic data.

Panning (1962) created two groups of species assigned to *Pseudocnus* Panning, 1949: those with both distally spinous pine-cone-shaped knobbed plates and knobbed buttons in the

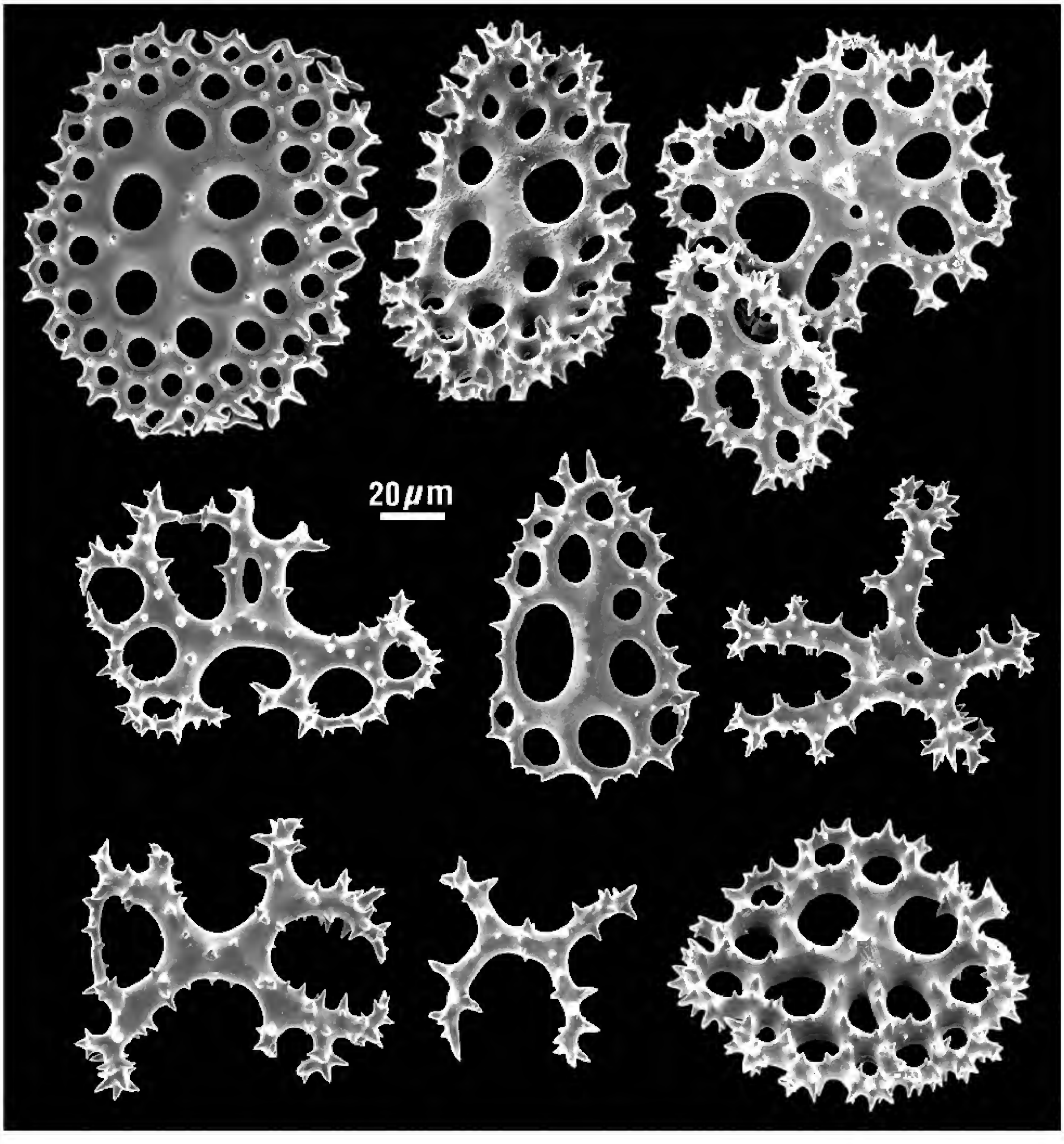

Figure 8. SEM images of peri-anal spinous cross and spinous plate ossicles from specimen of *Cladodactyla sicinski* (O'Loughlin, 2013) (NMV F193771).

body wall were assigned to the "*dubiosus* group"; those that lacked knobbed buttons were assigned to the "*laevigatus* group". We agree with this distinction between two morphologically distinct groups. Our limited genetic data support a "*laevigatus* group" clade (Fig. 9), and this clade shows geographic cohesion; all species live in the sub-antarctic – Antarctic region. *Pseudocnus leoninus*, the only sub-antarctic member of Panning's "*dubiosus* group" (with a complete cover of tube feet and numerous knobbed buttons in the body wall), genetically groups with Panning's "*laevigatus* group" (Fig. 9). We describe a new genus below, *Laevocnus* O'Loughlin gen. nov., that includes most species of Panning's "*laevigatus* group", and provisionally includes *P. leoninus*.

In contrast, North Pacific species assigned to *Pseudocnus* (including *P. curatus, P. lubricus, P. californicus*) are closely related to North Pacific species of *Cucumaria* (Arndt *et al.* 1996, Michonneau *et al.* in prep.), and do not cluster near the *Laevocnus* clade. Lambert (1998) judged that sub-species *Cucumaria fisheri astigmata* Wells, 1924 is conspecific with *Pseudocnus lubricus* (H. L. Clark, 1901). Lambert (1998) further judged that *Cucumaria curata* Cowles, 1907 should be retained in *Pseudocnus* and proposed a third "*curatus* group" for *Pseudocnus* species. *Pseudocnus curatus* (Cowles) has smooth buttons, with a few perforations only, in the body wall.

Thandar (1987) transferred four species from *Pseudocnus* to his new genus *Pseudocnella* Thandar, 1987: *Cucumaria sinorbis* Cherbonnier, 1952 (type species), *Cucumaria insolens* Théel, 1886 (junior synonym *Cucumaria leonina* var. *africana* Britten, 1910), *Semperia sykion* Lampert, 1885 (junior synonym *Cucumaria jaegeri* Lampert, 1885), and *Cucumaria syracusana* Grube, 1840.

P. cornutus (Cherbonnier, 1941) (Patagonia) was included in the "*laevigatus* group" by Panning and fits geographically there also. It differs from *Pseudocnus* species *sensu stricto* by having two smaller ventral tentacles, having tube feet radial only, and lacking buttons. It groups with species of the new

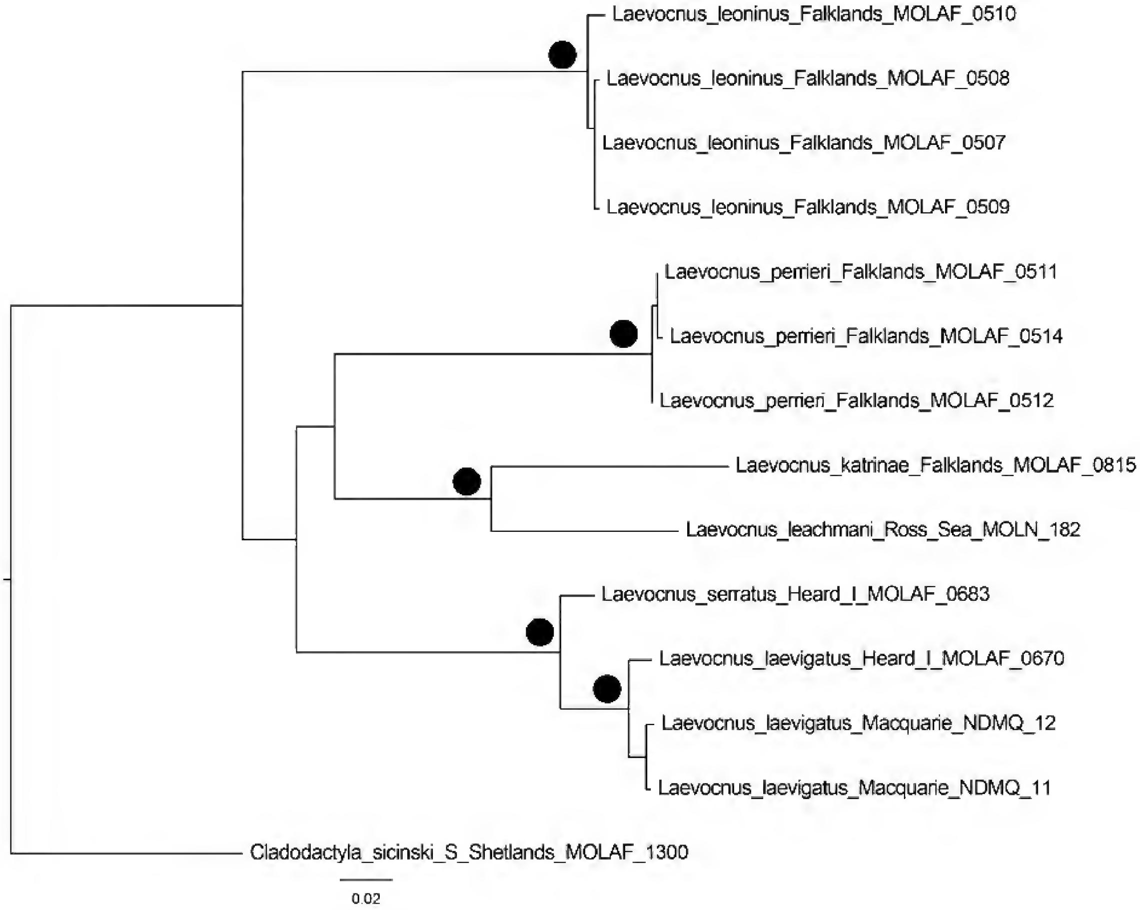

Figure 9. Maximum likelihood tree for *Laevocnus* clade, based on COI sequences, GTR+I model, 100 bootstrap replicates, *Cladodactyla sicinski* as outgroup. Filled circles >0.95 bootstrap support.

Table 2. Species remaining assigned to *Pseudocnus* in this work, most atypical for the genus *sensu stricto*, with the appropriate exception of *P. koellikeri* and the possible exception of *P. salmini* (see Remarks).

Species of *Pseudocnus*	**Occurrence**	**Morphological characters**
P. alcocki (Koehler and Vaney, 1908)	Andaman Islands	2 smaller ventral tentacles; tube feet radial only; body wall with small smooth buttons only
P. californicus (Semper, 1868)	California	2 smaller ventral tentacles; tube feet radial only; body wall lacking knobbed buttons
P. curatus (Cowles, 1907)	California	body wall with thick smooth buttons with few perforations only, lacking distally spinous plates
P. dubiosus (Semper, 1868)	Peru	2 smaller ventral tentacles
P. echinatus (von Marenzeller, 1881)	Japan	2 smaller ventral tentacles; tube feet radial only; body wall with knobbed plates with long pointed spire
P. goreensis (Cherbonnier, 1949)	Senegal	2 smaller ventral tentacles; multi-layered plates present in body wall
P. grubei (von Marenzeller, 1874)	Adriatic Sea	2 smaller ventral tentacles; tube feet radial only; body wall with *curatus*-like and multi-layered ossicles
P. koellikeri (Semper, 1868)	Mediterranean Sea	10 equal tentacles and as diagnosed
P. lamperti (Ohshima, 1915)	Aleutian Islands	2 smaller ventral tentacles; tube feet radial only; body wall lacking knobbed buttons
P. lubricus (H. L. Clark, 1901) (= *C. fisheri astigmata* Wells, 1924 (by Lambert 1998))	Puget Sound	tube feet scattered dorsally; body wall with distally spinous plates and knobbed buttons
P. pawsoni Won and Rho, 1998	Korea	2 smaller ventral tentacles; inter-radial tube feet small, scattered; body wall with *curatus*-like and multi-layered ossicles
P. rhopalodiformis (Heding, 1943)	Congo	rhopalodinid body form; 2 smaller ventral tentacles; tube feet radial only
P. rugosus Cherbonnier, 1957	Sierra Leone	2 smaller ventral tentacles; tube feet radial only; body wall with multi-layered ossicles
P. salmini (Ludwig, 1875)	Indonesia	as for P. *dubiosus*
P. sentus O'Loughlin and Alcock, 2000	New Zealand	2 smaller ventral tentacles; body wall with multi-layered distally spinous ossicles
P. spinosus (Ohshima, 1915)	Japan	2 smaller ventral tentacles; tube feet radial only; body wall lacking knobbed buttons
P. thandari Moodley, 2008	South Africa	2 smaller ventral tentacles; tube feet radial only

genus (below) by having tube feet confined to the radii and lacking buttons, but differs by having two smaller tentacles and having rod-plate ossicles and not plates in the tentacles. We provisionally refer *P. cornutus* to *Laevocnus* (below).

The species that remain assigned to *Pseudocnus* exhibit a range of contrasting morphological characters: 10 dendritic tentacles that may be equal or eight large and two small ventral; tube feet completely restricted to radii, largely restricted to radii, or uniformly distributed around body; macroscopic external anal scales present or absent; 'calcareous' ring calcified or not; body wall ossicles in different combinations with single-layered perforated knobbed plates with one end tapered and distally spinous (pine cone shape, pear shape) present or absent, knobbed buttons present or absent, multi-layered perforated knobbed plates present or absent, incomplete baskets present or absent, thick smooth buttons with few perforations only present or absent. We judge that species with such different combinations of morphological characters are not congeneric (see Table 2). None occurs in southern cold temperate to Antarctic waters. A further review of the species that remain assigned to *Pseudocnus* is needed.

Laevocnus O'Loughlin gen. nov.

Zoobank LSID. http://zoobank.org:act:6A6572E8-B33F-4200-80F8-5963E557DE65

Key 1; figure 9

Diagnosis. Ten equal dendritic tentacles; tube feet on radii only, radial series cross introvert to base of tentacles; 'calcareous' ring lacking posterior prolongations; ring sometimes not calcified in larger specimens; gonad tubules not branched; body wall ossicles single-layered perforated knobbed plates with one end tapered and distally spinous; lacking four-holed knobbed buttons; tentacles ossicles perforated plates, rarely rods, never rosettes.

Type species. Pentactella laevigata Verrill, 1876a, b (type locality Kerguelen Islands)

Assigned species and occurrence. Laevocnus cornutus (Cherbonnier, 1941) (Patagonia); *L. intermedius* (Théel, 1886) (Heard and Kerguelen Islands); *L. katrinae* O'Loughlin sp. nov. (Shag Rock); *L. laevigatus* (Verrill, 1876a, b) (Kerguelen Is); *L. leachmani* Davey and O'Loughlin sp. nov. (Ross Sea); *L. leoninoides* (Mortensen, 1925a) (New Zealand sub-antarctic islands); *L. leoninus* (Semper, 1867) (Falkland Is); *L. marionensis* (Théel, 1886) (Marion I.); *L. perrieri* (Ekman, 1927) (Falkland Is, South Georgia); *L. serratus* (Théel, 1886) (Heard I.).

Etymology. Formed from a combination of "*laev*" from *laevigata* (the species name of the type for the new genus), with the established and related generic name *Ocnus* (masculine).

Remarks. We judge that having 10 equal tentacles or eight large and 2 small ventral ones is a significant distinguishing generic character. Cherbonnier 1941 reported that his species *P. cornutus* had two slightly small ventral tentacles. No other *Laevocnus* species has other than 10 equal tentacles. *Laevocnus* species are distinguished from *Pseudocnus* species (*sensu stricto*) by: lacking inter-radial tube feet; having ossicles in the body wall limited to single-layered knobbed plates with spines at one end; rarely having rods and never rosettes in the tentacles.

As noted above in the previous Remarks *Laevocnus leoninus* is an anomalous inclusion in *Laevocnus*, having: a uniform cover of tube feet; numerous buttons in the body wall; and tentacle rods. It does have 10 equal tentacles. *Laevocnus leoninus* is sympatric with *Laevocnus perrieri* as a cold temperate species of the new genus. Also noted above is the provisional inclusion of *Laevocnus cornutus* that has two smaller tentacles and rod-plates in the tentacles.

Laevocnus marionensis is also a somewhat anomalous inclusion as it has body wall ossicles with slightly developed tapered spinous ends inter-grading with knobbed buttons that usually show some distal development.

O'Loughlin (2009) assigned *Cucumaria serrata* var. *intermedia* Théel, 1886 (Heard and Kerguelen Islands) and *Cucumaria serrata* var. *marionensis* Théel, 1886 (Marion Island) to *Pseudocnus* and raised them to species status. We now reassign these species to *Laevocnus.*

O'Loughlin (1994) reported that *Laevocnus laevigatus* exhibited brood-protection in "two ventral invaginated marsupia that opened through a common mid-body vestibule". In some female specimens (NMV F165742 (6)) of *Laevocnus serratus* we observed two ventral brood pouches invaginated into the coelom, with one or two ventral inter-radial external openings. There were up to 40 brood juveniles in one individual, each up to 3 mm long, sub-equal in size, and with their tentacle crowns developed. Two ventral openings but no internal pouches were observed (specimen NMV F84982) for *Laevocnus intermedius* and it is assumed that this species also has this brood-protecting adaptation.

COI sequence data from several hundred dendrochirotids (Michonneau *et al.* in prep) recovers *Laevocnus* as a single clade, albeit poorly supported, that includes *L. katrinae* sp. nov., *L. laevigatus, L. leachmani* sp. nov., *L. leoninus, L. perrieri* and *L. serratus* (Fig. 9).

Key (1) to the species of ***Laevocnus*** O'Loughlin gen. nov.

1. Tube feet cover the body uniformly .... ***Laevocnus leoninus*** (Falkland Is)
— Tube feet restricted to the radii **2**
2. Tube feet in single well-spaced series in mid-body on all radii **3**
— Close zig-zag or paired series of tube feet on all radii, may be more scattered on dorso-lateral radii **5**
3. Body up to 40 mm long; tube feet in paired series anteriorly; body wall ossicles with long, narrow "goose neck", ending in a sparsely perforated and spinous taper .... ***Laevocnus serratus*** (Heard I.)
— Body up to 15 mm long; single series of tube feet anteriorly; body wall ossicles with short tapered spinous end **4**
4. Calcareous ring thin and indistinct; two polian vesicles; body wall ossicles smaller, up to 208 μm long .... ***Laevocnus katrinae*** sp. nov. (western Antarctica, Shag Rock, 206 m)
— Calcareous ring distinct; single polian vesicle; body wall ossicles larger, up to 280 μm long .... ***Laevocnus leachmani*** sp. nov. (eastern Antarctica, Ross Sea and off King George V Land, 299–1645 m)
5. Body wall ossicles with spinous end predominantly rounded or not significantly elongate and tapered; body wall ossicles small, up to 160 μm long **6**
— Body wall ossicles with distal spinous end typically elongate and tapered; largest body wall ossicles longer than 180 μm long **7**
6. Body wall ossicles irregularly oval, predominantly with one end rounded and closely spinous, up to 140 μm long; tentacles ossicles large smooth perforated plates; preserved specimens smaller, up to 35 mm long .... ***Laevocnus leoninoides*** (New Zealand sub-antarctic Is)
— Body wall ossicles with slightly developed tapered spinous ends, inter-grading with knobbed buttons usually showing some distal development, up to 160 μm long; tentacles ossicles perforated plates with surface spines; preserved specimens larger, up to 55 mm long .... ***Laevocnus marionensis*** (Marion I.)
7. Two smaller tentacles; rod-plate ossicles in the tentacles .... ***Laevocnus cornutus*** (Patagonia, Falkland Is)
— Equal tentacles; plate ossicles in the tentacles **8**
8. Preserved specimens small, up to 40 mm long; tentacle plates with some surface spines; lacking ventral coelomic brood sacs and openings .... ***Laevocnus perrieri*** (Falkland Is, South Georgia)

— Largest preserved specimens up to at least 60 mm long; tentacle plates with knobs or smooth, not with surface spines; females with ventral coelomic brood sacs and openings **9**

9. Preserved body up to 115 mm long; body wall ossicles up to 220 μm long; tentacles ossicles smooth plates .... ***Laevocnus laevigatus*** (Kerguelen Is)

— Preserved body up to 65 mm long; body wall ossicles up to 185 μm long; tentacle ossicles plates with surface knobs .... ***Laevocnus intermedius*** (Heard I.)

Laevocnus katrinae O'Loughlin sp. nov.

Zoobank LSID. http://zoobank.org:act:AC9E8725-E167-405E-BCAA-3904F35161D6

Key 1; figures 9, 10

Material examined. Holotype. Southern Atlantic Ocean, Western Antarctica, Shag Rock, 53.63°S 40.91°W, 206 m, BAS BIOPEARL 1 stn SR–EBS–4, 11 Apr 2006, NMV F168836 (UF tissue sequence code MOL AF 815).

Paratypes. Type locality and date, NMV F 189886 (9); type locality and date, NHMUK 2010.139–142 (4).

Description. Up to 14 mm long, 4 mm diameter (tentacles deeply withdrawn); body cylindrical, rounded orally and anally; thin, semi-translucent, calcareous body wall; 10 equal dendritic tentacles; calcareous ring present, indistinct, thin sinusoidal cucumariid-like, lacking posterior prolongations; tube feet extended, rigid, about 0.3 mm diameter, restricted to single well-paced radial series, up to 7 tube feet per series externally, plus up to 9 per series on withdrawn introvert; 5 small anal papillae; lacking macroscopic anal scales; 2 polian vesicles; 2 tufts of un-branched gonad tubules.

Ossicles in body wall similar in smallest (2 mm long) and largest specimens, elongate to irregularly-oval perforated plates, with marginal and surface knobs, tapered at one end, there bearing distal spines, plates up to 208 μm long. Ossicles in tentacles irregularly rectangular to triangular perforated plates with denticulate to spinous margins and few small surface granulations, up to 180 μm long. Ossicles in tube feet endplates with small irregular perforations; tube feet support ossicles irregularly-curved, perforated plates, frequently with distally-spinous mid-plate projection, plates up to about 200 μm long. Peri-anal ossicles distally spinous knobbed plates as in mid-body wall.

Colour (preserved). Body and tentacles white.

COI DNA barcode of holotype: AATTATGATAGGAGGCTTTGGAAACTGATTAATACCTTTAATGATAGGAGCCCCCGATATGGCTTTCCCACGAATGAACAATATGAGATTCTGATTAATACCCCCTTCTTTTATTTTACTATTGGCTTCTGCTGGAGTAGAAGGAGGTGCAGGAACAGGATGAACTATTTACCCACCTTTATCCAGAAAAATAGCTCATGCAGGAGGATCTGTAGATTTAGCTATATTTTCCCTACACTTAGCAGGTGCCTCCTCAATACTTGCATCTATTAAATTTATTACTACTATTATAAATATGCGAGCACCAGGAGTTTCATTTGATCGTTTACCACTATTTATTTGATCAGTTCTAATAACCGCCTTTCTTTTACTTCTAAGTCTTCCTGTTTTAGCAGGTGCTATTACAATGTTATTAACAGACCGAAATATAAAAACAACTTTTTTTGATCCATCAGGAGGAGGAGACCCTATACTATTTCAACACTTATTTTGATTTTTTGGACACCCTGAAGTTTATATTTTGATTCTACCAGGATTTGGAATGATATCACACGTAATTACTCATTATAGAGGTAGACAAGAACCATTTGGATATTTAGGAATGGTTTATGCTATGATAGCTATAGGTATTTTAGGTTTTATCGTGTGAGCACAC

Distribution. Southern Atlantic Ocean, Western Antarctica, Shag Rock, 206 m.

Etymology. Named for Katrin Linse (British Antarctic Survey), in appreciation of her role in the BAS BIOPEARL expeditions and the collection of specimens studied here, and with gratitude for her gracious collaboration in making BAS specimens available for this study and providing relevant data.

Remarks. Laevocnus katrinae is distinguished from other species of *Laevocnus* by the morphological characters detailed in the key above, as well as by >17% pair-wise K2P divergence in CO1 sequence.

Laevocnus leachmani Davey and O'Loughlin sp. nov.

Zoobank LSID. http://zoobank.org:act:DD44CDAF-F84B-4D6F-B979-FCB0EBD60015

Key 1; figures 9, 11

Pseudocnus species (Ross Sea) O'Loughlin *et al.*, 2010: table 1.

Material examined. Holotype. Eastern Antarctica, Ross Sea, 72.08°S 175.55°E, 1620 m, stn TAN0802/139, N. Davey, 22 Feb 2008, NIWA 42203 (UF tissue sequence code MOL N 182).

Paratype. Type locality and date, NIWA 61890 (1).

Other material. Ross Sea, 72.07°S 175.59°E, 1629–1645 m, stn TAN0802/135, 22 Feb 2008, NIWA 61100 (4 juvenile specimens); off George V Land, 66.57°S 142.00°E, 299–521 m, CEAMARC RSV *Aurora Australis* Voyage 3, stn 9EV117, 26 Dec 2007, NMV F189887 (1).

Description. Body up to 15 mm long (preserved, tentacles withdrawn), 6 mm diameter; body fusiform; body wall thin, calcareous, with a rugose surface created by a close cover of projecting spinous ossicle ends; 10 equal dendritic tentacles; 5 oral papillae, 5 anal papillae, lacking anal scales; tube feet projecting, not withdrawn, about 0.4 mm in diameter, restricted to a single, well-spaced series in all radii, extending across the introvert; calcareous ring distinct, calcified, cucumariid-like, lacking posterior prolongations; single polian vesicle; two tufts of unbranched gonad tubules; 3 embryos in withdrawn oral cavity in one specimen.

Body wall ossicles irregularly oval to oblong, single-layered, perforated, knobbed plates, with one end of plate always sharply spinous and frequently narrowed into a short distally-spinous neck, spinous apex frequently upturned, plate perforations smaller at ends, sometimes with two large perforations centrally separated by a narrow knobbed bridge, plates up to 280 μm long; lacking knobbed buttons. Tentacle ossicles perforated plates of variable form and size, up to 240 μm long, marginally

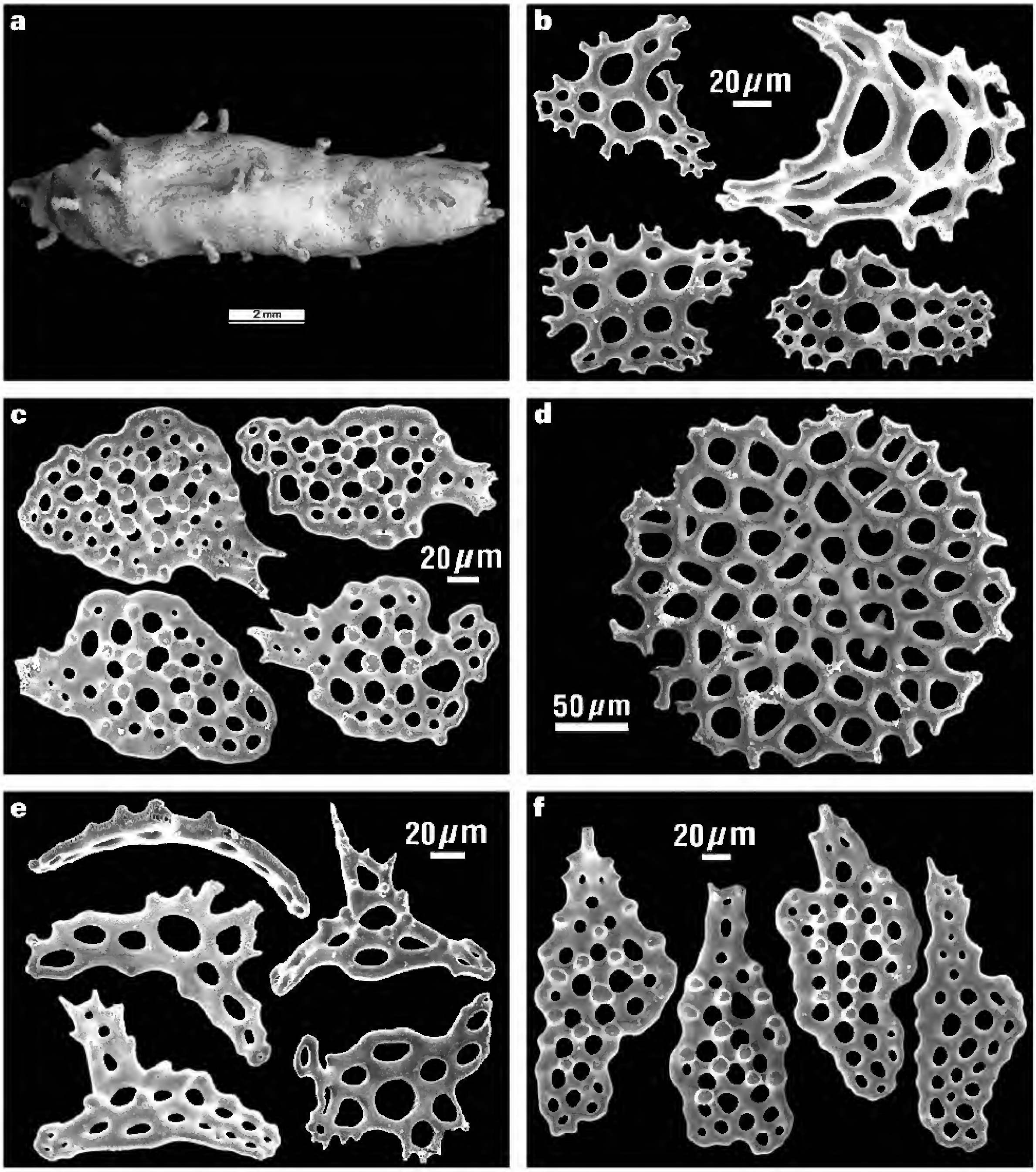

Figure 10. *Laevocnus katrinae* O'Loughlin sp. nov. holotype (NMV F168836). a, preserved holotype; b–f, SEM images of ossicles from the holotype – b, tentacle plates; c, mid-body wall plates with one end distally spinous; d, tube foot endplate; e, endplate support ossicles with distally spinous lateral projection; f, peri-anal plates with one end distally spinous.

spinous, sometimes with surface knobs or spines; no rods or rosettes. Tube feet endplate support ossicles bent and curved plates with apically spinous mid-plate projection.

Colour (preserved). White.

COI DNA barcode of holotype: TAACTGATTAATACCTTTAATGATTGGAGCCCCTGACATGGCTTTCCCACGAATGAACAATATGAGATTCTGATTAATACCCCCATCCTTTCTTTTACTACTAGCTTCTGCTAGTGTAGAAAGAGGTGCAGGAACAGGATGAACTATTTACCCCCCCTTATCTAGAAAAATAGCCCATGCAGGAGGATCTGTAGATCTAGCTATTTTTTTCACTTCACCTAGCAGGTGCCTCTTCAATTCTTGCAGCTATAAAATTTATAACTACTATAATAAAAATGCGAGCACCAGGTATTTATTTTGACCGTCTATCATTATTTATCTGATCCGTCTTTATTACTGCTTTTCTATTACTCTTAAGTCTTCCAGTATTAGCAGGTGCTATTACAATGTTATTAACAGATCGAAACATAAACACTACCTTCTTTGATCCATCAGGTGGAGGAGATCCTATATTATTCCAACACTTATTCTGATTTTTTGGACACCCAGAAGTATATATTCTTATTTTACCAGGATTTGGTATGATATCTCATGTAATTACACATTATAGAGGAAGACAAGAACCCTTTGGATATTTAGGTATGGTTTATGCTATGATATCTATAGGTATTTTAGGTTTCCTAGTATGAGCTCACCACATGTTTACTGTAGGA

Distribution. Eastern Antarctica, Ross Sea and off George V Land, 299–1645 m.

Etymology. Named for Andrew Leachman, skipper of the RV *Tangaroa* for 38 years, that included seven marine research voyages to Antarctica.

Remarks. Laevigatus leachmani is distinguished from other species of *Laevocnus* by the morphological characters detailed in the key above, as well as by >17% pair-wise K2P divergence in CO1 sequence. This species is listed as *Pseudocnus* species (Ross Sea) by O'Loughlin *et al.* (2010) (Table 1).

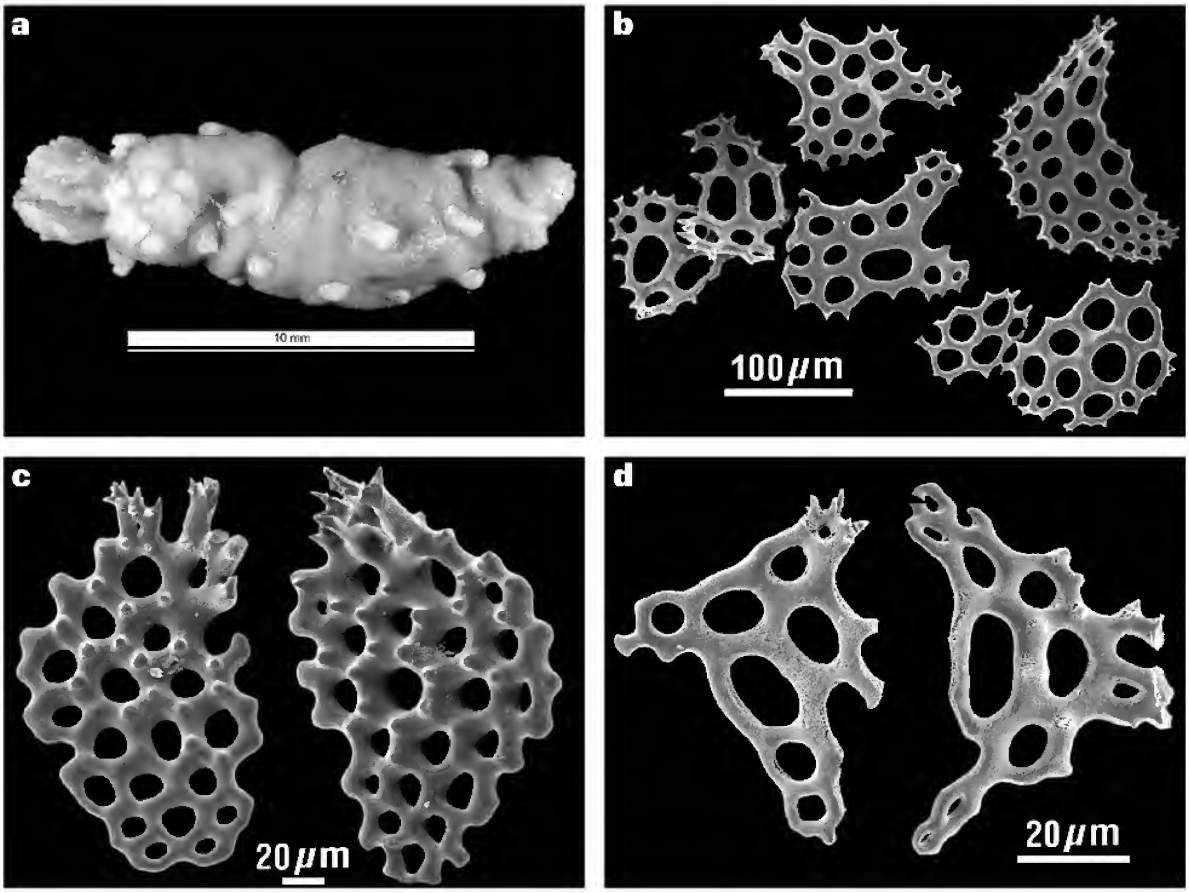

Figure 11. *Laevocnus leachmani* Davey and O'Loughlin sp. nov. a, preserved holotype (NIWA 42203; photo by Peter Marriot (NIWA)); b–d, SEM images of ossicles from a paratype (NIWA 61890) – b, tentacle plates; c, mid-body wall plates with one end distally spinous; d, tube foot endplate support ossicles, one with distally spinous lateral projection.

Family **Paracucumidae** Pawson and Fell, 1965

Key 2; figure 12

Diagnosis. Body cylindrical, posterior taper; body wall thin; tube feet distributed around body; 10–15 dendritic or sub-digitiform tentacles, ventral pair usually small; mid-body wall ossicles perforated plates, some with knobs, some with secondary layer developments from one or a few layers to dome-like stacks or spines, sometimes in cross form.

Included genera. *Paracucumis* Mortensen, 1925b; *Crucella* Gutt, 1990

Remarks. Gutt (1990) referred his new genus *Crucella* to the Paracucumidae, and O'Loughlin (2002) and O'Loughlin *et al*. (2009b) maintained this referral. O'Loughlin *et al*. (2009b) discussed *Crucella*, judged that *Caespitugo citriformis* Gutt, 1990 is a junior synonym of *Thyone scotiae* Vaney, 1906 and referred *Thyone scotiae* to *Crucella*. Currently the family has three recognized species: *Paracucumis turricata* (Vaney, 1906) (junior synonym *Paracucumis antarctica* Mortensen, 1925b by O'Loughlin 2002), *Crucella scotiae* (Vaney, 1906), and *Crucella hystrix* Gutt, 1990. We add a fourth species *Crucella susannae* O'Loughlin sp. nov. Phylogenetic analysis based on CO1 sequence data recovers a monophyletic Paracucumidae among 200 species of dendrochirotids sequenced to date, but shows *Crucella*, as currently defined, to be paraphyletic (Fig. 12), with *C. scotiae* sister to the new species *C. susannae* and *P. turricata* sister to these two species. However *P. turricata* has what we judge to be two significant morphological characters (up to 15 tentacles and body wall plates imbricating or contiguous) that are not shared with *C. scotiae* and *C. susannae*. We acknowledge this anomaly for generic assignment, but on primarily morphological grounds maintain *Thyone scotiae* in *Crucella* and maintain *Paracucumis* as a monotypic genus. CO1 data indicate further cryptic, geographical divergence within *C. hystrix* and *C. scotiae* as previously indicated by O'Loughlin *et. al*. (2010). We note in relation to the 2010 paper and relevant tree (page 8) that the South Shetland specimen (green) of *C. scotiae* is re-identified here as our new species *C. susannae*.

Key (2) to the species of Paracucumidae (Antarctica)

1. Body form elongate, narrow, vermiform; plates covering body wall imbricate or contiguous; body cover of high domes on plates; tube feet around body mostly inconspicuous; up to 15 dendritic tentacles .... ***Paracucumis turricata***

— Body form not elongate, narrow, vermiform; plates in mid-body wall not imbricate, some contiguous; body with or lacking domes or fine spines on plates; tube feet around body conspicuous; 10 tentacles **2**

2. Preserved body up to 30 mm long; finely spinous surface appearance; tentacles sub-digitiform; knobbed perforated cross ossicles in mid-body wall, some with narrow spires .... ***Crucella hystrix***

— Preserved body up to at least 50 mm long; wide blunt domes or smooth surface appearance; tentacles dendritic; mid-body plate ossicles never in cross form **3**

3. Uniform cover of tube feet; mid-body wall ossicles include large irregular plates (up to 600 μm long), some with secondary layering and central elevation forming a low dome .... ***Crucella scotiae***

— Tube feet closer together and larger ventrally than dorsally; mid-body wall ossicles round to oval single-layered perforated plates (up to 170 μm long), never with secondary layering .... ***Crucella susannae***

Crucella Gutt, 1990

Key 2; figure 12

Diagnosis (emended). Body cylindrical, not vermiform, with narrowed tail; body wall thin; 10 dendritic or sub-digitiform tentacles, ventral pair small; tube feet distributed around body, sometimes unevenly; body wall ossicles perforated plates, some with knobs, some with low secondary layering forming domes, some with spires; mid-body plates generally spaced apart, some plates possibly contiguous but not imbricating.

Type species. *Crucella hystrix* Gutt, 1990 (type locality Weddell Sea)

Assigned species and type locality. *Crucella hystrix* Gutt, 1990 (Weddell Sea); *C. scotiae* (Vaney, 1906) (Antarctic Peninsula); *Crucella susannae* O'Loughlin sp. nov. (South Shetland Islands)

Remarks. *Crucella* is reviewed above in the Remarks and Key for Paracucumidae.

Crucella susannae O'Loughlin sp. nov.

Zoobank LSID. http://zoobank.org:act:962A6E3A-4177-4585-A1BB-A4AC17FD1E90

Key 2; figures 12, 13, 14

Material examined. Holotype. Antarctica, South Shetland Islands, off King George Island, 61.83°S 58.63°W, 191 m, CCAMLR RV *Polarstern* ANT–XXVIII/4 stn 79/264, S. Lockhart, 31 Mar 2012, NMV F193782.

Paratypes. Off Elephant Island, 60.98°S 55.69°W, 92 m, CCAMLR RV *Polarstern* ANT–XXVIII/4 stn 79/229, 24 Mar 2012, NMV F193784 (17) (UF tissue sequence code MOL AF1293); Bransfield Strait, 62.45°S 055.27°W, 244 m, CCAMLR RV *Polarstern* ANT–XXVIII/4 stn 79/269, 1 Apr 2012, NMV F198491 (1); South Orkney Islands, 60.59°S 45.15°W, AMLR 2009 stn 78/8, 92–105 m, 11 Feb 2009, NMV F169315 (1).

Description. Up to 52 mm long, 28 mm diameter (strongly contracted, tentacles deeply withdrawn); body bluntly rounded and upturned orally, tapered upturned cone-shaped anally; body wall thin, firm, parchment-like to soft leathery; 8 large, 2 small ventral, dendritic tentacles; solid typical cucumariid calcareous ring present, lacking any posterior prolongations; completely covered with small tube feet, close-set and about 0.4 mm diameter ventrally, scattered and about 0.2 mm diameter dorsally; with numerous small peri-anal papillae; lacking macroscopic anal scales; 2 tufts of gonad tubules, not branched; respiratory trees present; 1 polian vesicle.

Dorsal body wall with scattered, not imbricating or contiguous, thick, single-layered, oval to round plates, with up to 22 perforations, irregular margins sometimes with blunt denticulations, sometimes with surface knobs, up to 168 μm long. Ventral body wall ossicles similar to dorsal. Tentacles with perforated plates and long, narrow, perforated, rod-like plates, with marginal digitiform and blunt denticulations, plates smooth or with some surface knobs, up to 560 μm long. Ventral tube feet with endplates with rounded margin, large and small perforations irregularly arranged, up to 360 μm diameter; lacking tube foot support ossicles. Peri-anal ossicles include plates as in body wall; numerous larger, oval, perforated plates with low secondary layering, up to 280 μm long; and pyramidal multi-layered anal scales, about 360 μm high and wide at base.

Colour. Live: Body pale brown and blue-grey. Preserved: pale brown to grey to off-white.

COI DNA barcode of paratype: TATTATGATAGGAGGTTTTGGTAATTGGTTAATTCCATTAATGATAGGAGCACCAGACATGGCCTTCCCTCGAATGAATAAAATGAGATTCTGATTAATTCCCCCTTCTTTTGTGCTTCTGCTTACCTCCGCAAGAATAGAAAATGGGGCTGGTACAGGTTGAACTTTATACCCCCCTCTTTCAAGAAAAATAGCTCACGCAGGAAGATCAGTAGATCTTGCTATTTTTTCGCTACATCTAGCAGGAGCCTCCTCTATTCTTGCCTCCATAAAATTTATAACTACCATAATAAAAATGCGAACCCCAGGAATTTCATTTGACCGTCTACCACTTTTTGTCTGATCCGTTTTTATAACAGCCTTCCTATTAGTATTAAGCCTCCCAGTTTTAGCAGGTGCTATAACAATGTTATTAACCGACCGAAAAATTAAAACAACCTTCTTTGACCCAGCAGGAGGAGGAGACCCCATTTTATTTCAACACTTATTCTGATTCTTTGGACATCCAGAAGTTTATATACTTATTTTACCAGGGTTCGGAATGATATCTCACGTTATTGCACACTATAGAGGAAAGCAAGAACCATTTGGGTACTTAGGAATGGTTTACGCTATGGTAGCAATAGGAGTATTAGGCTTCCTAGTATGAGCTCAC

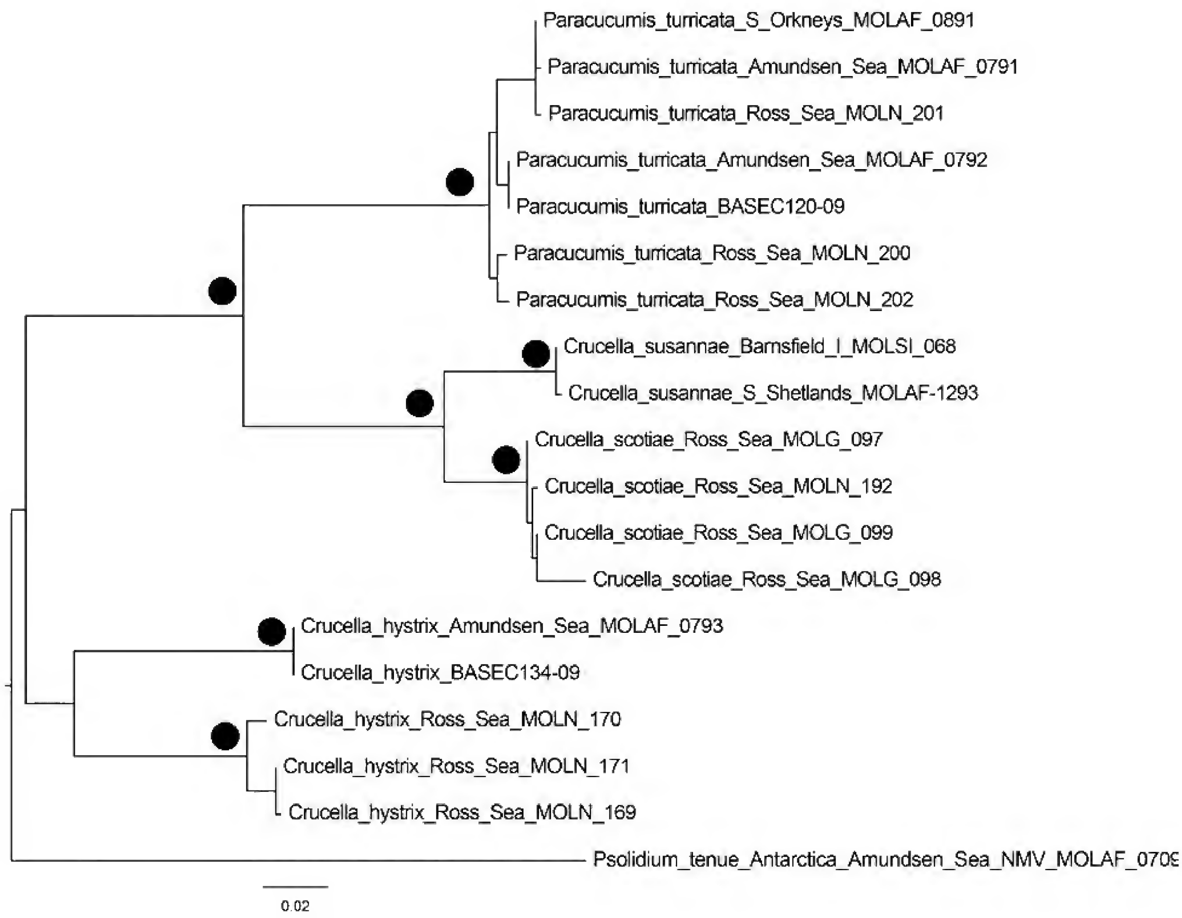

Figure 12. Maximum likelihood tree for Paracucumidae, based on COI sequences, GTR+G model, 100 bootstrap replicates, *Psolidium tenue* as outgroup. Filled circles >0.95 bootstrap support.

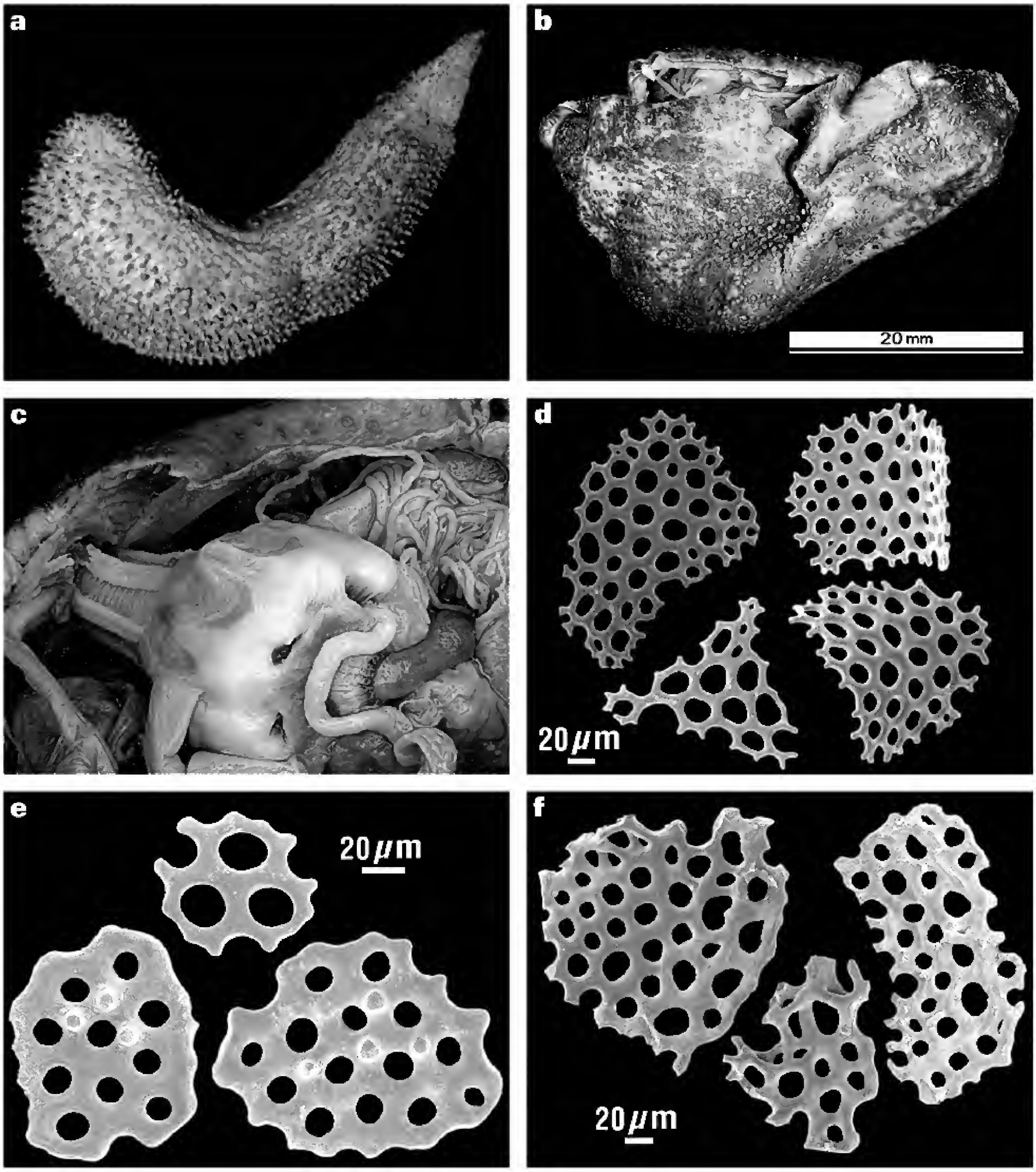

Figure 13. *Crucella susannae* O'Loughlin sp. nov. a, photo of live specimen of a paratype (Elephant I.; NMV F193784; photo by Susanne Lockhart); b–f, holotype (NMV F193782) – b, left lateral view of preserved body of holotype; c, calcareous ring, polian vesicle, gonad tubules; d, SEM images of tentacle ossicles; e, SEM images of body wall ossicles; f, SEM images of fragments of endplate.

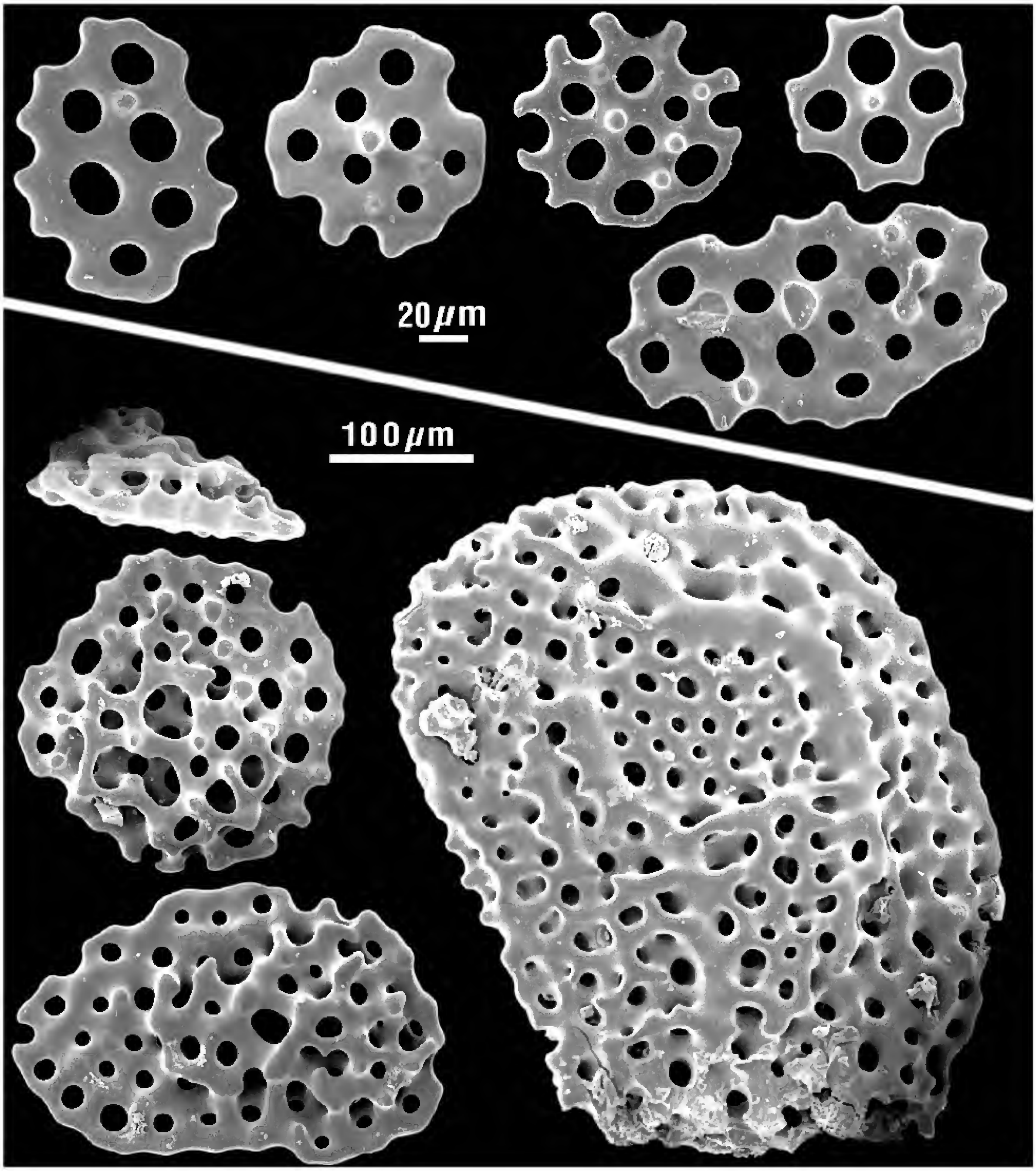

Figure 14. SEM images of peri-anal body wall ossicles from holotype of *Crucella susannae* O'Loughlin sp. nov. (holotype NMV F193782). Top: typical mid-body wall ossicles in the peri-anal region. Bottom: fragment of peri-anal scale with some secondary layer development, and perforated plates with secondary layer developments.

Distribution. Western Antarctica, South Shetland, Elephant, South Orkney Islands, 92–244 m.

Etymology. Named for Susanne Lockhart (National Oceanic and Atmospheric Administration's US AMLR Program), in appreciation of her initiative and hard-working role in quantitatively collecting, preserving, documenting and donating to Museum Victoria many hundreds of specimens of sea cucumbers from the 2012 CCAMLR demersal finfish trawl survey.

Remarks. *Crucella susannae* is distinguished from other species in family Paracucumidae in the key. We judge that the preserved dark brown colour of the holotype (NMV F193782) is a result of discolouration from trawl contents.

Paracucumis Mortensen, 1925b

Key 2

Diagnosis (emended). Body form cylindrical, elongate, narrow, vermiform, posterior tapered; body cover of high domed plates; up to 15 dendritic tentacles, ventral pair and possibly some others small; tube feet distributed around body, may be rudimentary and inconspicuous; plates covering body wall imbricate or contiguous, some multi-layered into a high dome-like elevation.

Type species. *Thyone turricata* Vaney, 1906 (= *Paracucumis antarctica* Mortensen, 1925b by O'Loughlin 2002) (type locality South Orkney Islands) (monotypic)

Remarks. *Paracucumis* is reviewed above in the Remarks and Key for Paracucumidae.

Family **Thyonidiidae** Heding and Panning, 1954

Diagnosis (Smirnov 2012). Tentacles 15–25; plates of calcareous ring lacking segmented posterior extensions; ossicles tables with 2, 3 or 4 pillars, or plates (*Parathyonidium*), or reduced (*Patallus* and *Athyonidium*).

Remarks. Thyonidiinae Heding and Panning, 1954 was raised to family status by Smirnov (2012) who understandably suspected that the Thyonidiidae is polyphyletic, those genera with tables not related to those lacking tables.

Parathyonidium Heding, 1954

Parathyonidium Heding, 1954 in Heding and Panning 1954.

Diagnosis (see *Description* of *Parathyonidium incertum* Heding, 1954 below)

Type species. *Parathyonidium incertum* Heding, 1954 (type locality South Georgia) (monotypic)

Remarks. Albert Panning (in Heding and Panning 1954) noted that his Copenhagen friend and colleague Sven Heding died before the publication of their anticipated *Discovery Report*, where he planned to describe the new genus *Parathyonidium* and species *Parathyonidium incertum*. Albert further noted that Elizabeth Deichmann had taken over work on the *Discovery* specimens, but had agreed that Albert would publish the description as written by Sven. Albert assigned the authorship of the new taxa to Heding, and the descriptions were published in Heding and Panning (1954). A *Discovery Report* on holothuroids was never published. The *Discovery* holothuroid collection is currently in Museum Victoria where most specimens have now been determined. Mark O'Loughlin and his colleagues hope to complete a *Discovery Report* on holothuroids. Here we have emended the diagnosis of *Parathyonidium* Heding, 1954 to more fully describe the tentacle form and arrangement, calcareous ring, gonad tubule arrangement, and ossicles.

Parathyonidium incertum Heding, 1954

Figure 15

Parathyonidium incertum Heding, 1954 in Heding and Panning 1954: 37–39, text fig. 3.—O'Loughlin *et al*., 2009b: 5–6, table 1, fig. 1d–f.—O'Loughlin *et al*., 2010: table 1.

Parathyonidium Heding species.—O'Loughlin *et al*., 2009a: 217, fig. 2c.

Parathyonidium species.—O'Loughlin *et al*., 2010: 4, table 1.

Material examined. Holotype. West of Shag Rock, South Georgia, *Discovery Expedition*, RRS *Discovery II* stn 474, 199 m, 12 Nov 1930, no registration found (data from Heding and Panning 1954; specimen not located).

Paratypes. South Shetland Islands, Clarence Island, Discovery Expedition, *Discovery* stn D170, 61°26'S 53°46'W, 342 m, 23 Feb 1927, NHMUK 2011.171–173 (3); ZMUC–HOL–300 (3) (confirmed by Tom Schioette ZMUC; specimens not seen here); Elephant I., 600 m, MNHN–IE–2013–2479 (2) (previously EcHh250, confirmed by Sébastien Soubzmaigne MNHN; specimens not seen here).

Other material. South Atlantic Ocean, South Georgia, US AMLR 2004, *Icefish* stn 47–BT25, 55.06°S 35.24°W, 116 m, 12 Jun 2004, NMV F104998 (1); Antarctic Peninsula, Low I., BENTART–2006, R/V *Hesperides*, stn LOW47, 63.47°S, 62.22°W, 115 m, 12 Feb 2006, MNCN 29.04/126 (1 specimen), body wall ossicles slide NMV F161525; MNCN 29.04/127 (2 specimens), posterior body ossicles slide NMV F161526, tentacle ossicles slide NMV F161527; Eastern Antarctica, off Enderby Land, *Nella Dan*, ANARE stn HRD010, 65°56'S 50°52'E, 386–400 m, M. Norman, 15 Nov 1985, NMV F84983 (15), NMV F165585 (1), NMV F189876 (4); stn HRD011, 65°50'S 50°35'E, 540 m, M. Norman, 20 Nov 1985, NMV F189880 (2).

Description (emended from O'Loughlin et al. 2009b). Specimens up to 35 mm long preserved (tentacles partly extended, NMV F104998), sub-cylindrical, elongate, widest diameter 5 mm; soft thick body wall; lacking distinct ventral sole; oral end sometimes upturned, slightly tapered and rounded distally when tentacles withdrawn; anal end slightly tapered and rounded distally; 13 to 16 dendritic tentacles (holotype with 13; NMV F104998 with 16; one paratype NHMUK 2011.171–173 with 15), typically in a single circle of 5 single, smaller, radial and 5 pairs of larger, inter-radial tentacles; long digitiform genital papilla posterior to dorsal tentacle pair immediately distal to tentacle crown in male specimen (suggesting internal fertilization and brood protection); female genital pore posterior to dorsal tentacle pair; tube feet large, confined to radii, spaced in single series

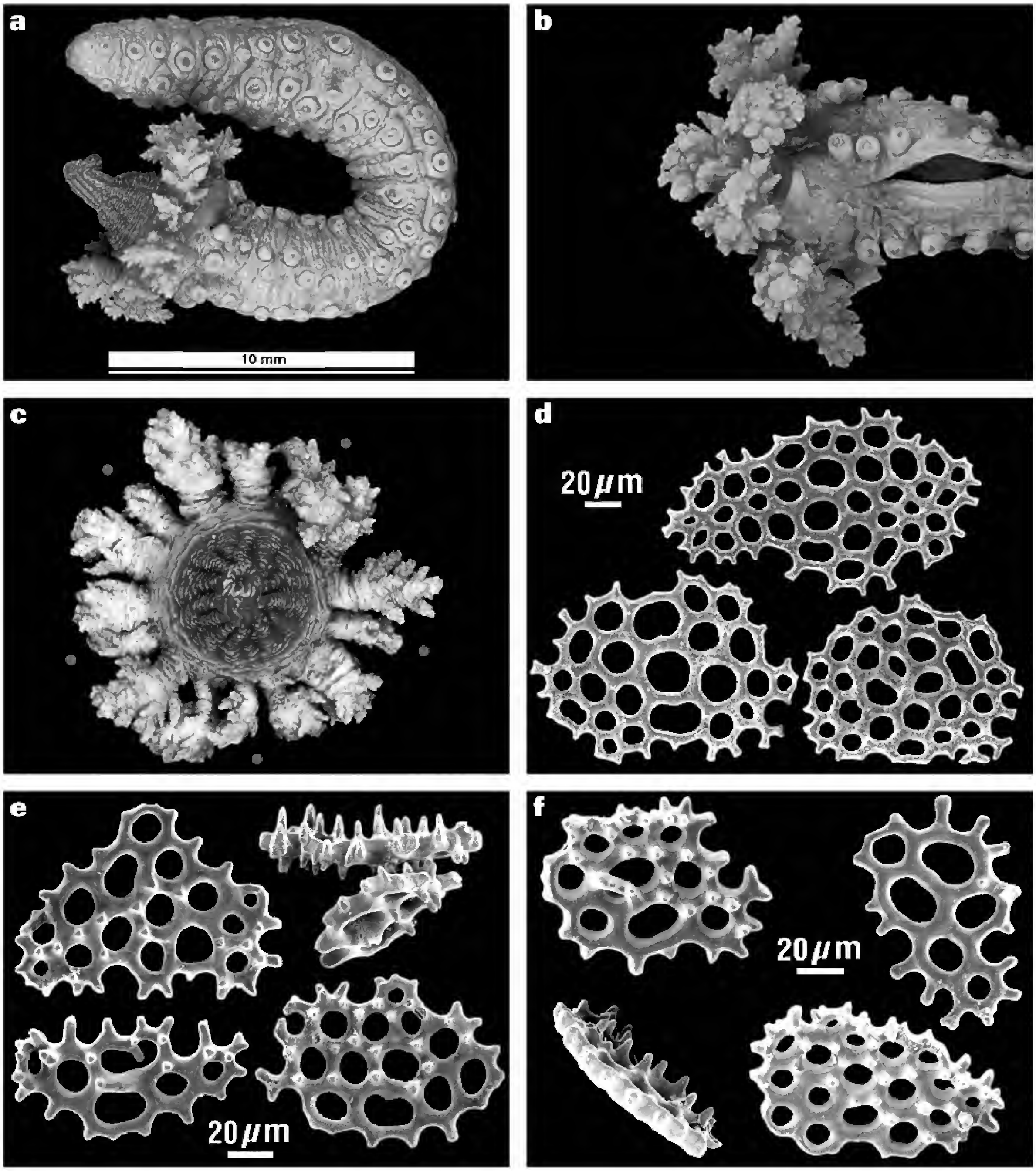

Figure 15. *Parathyonidium incertum* Heding, 1954. a–c, paratypes NHMUK 2011.171–173. a, specimen showing large radial tube feet, and smaller tentacle aligned with radius / ambulacrum (oeophagus everted); b, dorsal inter-radial male genital papilla immediately distal to tentacle crown; c, view of tentacle crown with smallest tentacles aligned with radii / ambulacra (denoted by red spot; top right small tentacle obscured by larger tentacle). d–f, specimen NMV F104998. d, SEM images of ossicles from tentacles; e, SEM images of ossicles from dorsal mid-body wall; f, SEM images of ossicles from ventral mid-body wall.

from base of tentacles to anus; calcareous ring with radial plates only, sub-rectangular, elongate, wide anteriorly and posteriorly, narrowed mid-plate, deep posterior notch; 1–2 long, tubular polian vesicles; no respiratory trees; gonad tubules in two tufts, not in series along gonoduct, one tuft on each side of dorsal mesentery, tubules not branched; brood-protection of free juveniles in the coelom.

Body wall ossicles two types of plates: abundant, thin, lattice-like, smooth to knobbed, single-layered, irregular plates, with bluntly denticulate margins, and with few to many perforations, similar dorsally and ventrally; and additional thin, elongate, plates, with 2 large central perforations, 2 small distal perforations, with one end extended with few small perforations, and with short blunt denticulations on surface and around margin, typically 100 μm long, but up to 160 μm long; these small plates intergrade with the larger smooth to knobbed, marginally denticulate plates, that are up to 200 μm long. Tube foot with large (up to 360 μm diameter) endplates, few perforated support plates. Tentacle ossicles perforated round to oval, slightly concave plates, with blunt marginal denticulations, some with central knob, some fine surface spines, plates up to 280 μm long; rods absent. Peri-anal body wall with incipiently multi-layered, thick, round, perforated plates / scales, 440 μm diameter.

Colour (preserved). Yellow-white, some specimens with a violet hue; purple internally (Heding 1954), pale grey (this work).

Distribution. South Atlantic, South Georgia, Shag Rock; Western Antarctica, Elephant I., South Shetland Is, Antarctic Peninsula; Eastern Antarctica, Enderby Land; 115–600 m.

Remarks. Heding and Panning (1954) makes clear reference to a "Type" from Shag Rock, and also refers in the description to additional specimens. This holotype has not been located in any of the European or United States museums. There are paratypes so labelled in the MNHN and ZMUC. Amongst the *Discovery Expedition* specimens there are three from Clarence Island in the South Shetland Islands (NHMUK 2011.171–173) that are from the same original lot as the labelled paratypes in Copenhagen (ZMUC–HOL–300 (3)). We have labelled and listed these NHMUK specimens as paratypes. We have found numerous specimens from off Enderby Land in Eastern Antarctica in the collections of Museum Victoria (NMV). These coelomic brood-protecting specimens were first thought to represent a new species (see O'Loughlin *et al.* 2009a, 2010), but we now judge that they are conspecific with *Parathyonidium incertum*. This is the only Antarctic coelomic brood-protecting species reported to date (see O'Loughlin *et al.* 2009a).

Acknowledgments

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Appendix 1. List of species, tissue sample code numbers, specimen repositories, specimen registration numbers, and GenBank Accession numbers.

Genus	**species**	**Sample number**	**Voucher repository**	**Catalog number**	**Location**	**GenBank Accession number**
Heterocucumis	steineni	MOLN_195	NIWA	35396	Ross Sea	HM196616.1
Heterocucumis	steineni	MOLAF_0785	NHM	2010.125-130	Amundsen Sea	HM196617.1
Heterocucumis	steineni	MOLSI_043	USNM	1132662	Bransfield Strait	HM196618.1
Heterocucumis	steineni	MOLN_194	NIWA	36744	Ross Sea	HM196619.1
Heterocucumis	steineni	MOLN_196	NIWA	42196	Ross Sea	HM196620.1
Heterocucumis	steineni	MOLN_197	NIWA	35675	Ross Sea	HM196621.1
Heterocucumis	steineni	MOLAF_0786	NHM	2010.125-130	Amundsen Sea	HM196622.1
Heterocucumis	steineni	MOLG_107	NIWA	60846	Ross Sea	HM196623.1
Heterocucumis	steineni	MOLSI_065	USNM	1132677	Bransfield Strait	HM196624.1
Heterocucumis	steineni	MOLG_106	NIWA	60855	Ross Sea	HM196625.1
Heterocucumis	steineni	MOLSI_026	USNM	1132644	Bransfield Strait	HM196626.1
Heterocucumis	steineni	MOLAF_0784	NHM	2010.124	Amundsen Sea	HM196627.1
Heterocucumis	steineni	MOLSI_037	USNM	1132658	Bransfield Strait	HM196628.1
Heterocucumis	steineni	MOLSI_050	USNM	1132668	Bransfield Strait	HM196629.1
Heterocucumis	steineni	MOLSI_038	USNM	1132658	Bransfield Strait	HM196630.1
Staurocucumis	liouvillei	MOLAF_0541	NMV	F104802	South Georgia	HM196658.1
Staurocucumis	liouvillei	MOLN_172	NIWA	36028	Ross Sea	HM196659.1
Staurocucumis	liouvillei	MOLSI_035	USNM	1132656	Bransfield Strait	HM196660.1
Staurocucumis	liouvillei	MOLN_173	NIWA	42158	Ross Sea	HM196661.1
Staurocucumis	liouvillei	MOLAF_0700	NMV	F165748	Heard Island	HM196662.1
Staurocucumis	liouvillei	MOLAF_0537	NMV	F160028	Bouvet Island	HM196663.1
Staurocucumis	liouvillei	MOLAF_0788	NHM	2010.168-173	Amundsen Sea	HM196664.1
Staurocucumis	liouvillei	MOLN_174	NIWA	36562	Ross Sea	HM196665.1
Staurocucumis	liouvillei	MOLAF_0539	NMV	F104986	Bouvet Island	HM196666.1
Staurocucumis	liouvillei	MOLAF_0783	NHM	2010.158-163	Amundsen Sea	HM196667.1
Staurocucumis	liouvillei	MOLAF_0781	NHM	2010.158-163	Amundsen Sea	HM196668.1
Staurocucumis	liouvillei	MOLAF_0787	NHM	2010.168-173	Amundsen Sea	HM196669.1
Staurocucumis	liouvillei	MOLAF_0540	NMV	F104800	Falkland Islands	HM196670.1
Staurocucumis	liouvillei	MOLN_175	NIWA	36904	Ross Sea	HM196671.1
Staurocucumis	krzysztofi	MOLSI_056	USNM	1132671	Bransfield Strait	HM196672.1
Staurocucumis	krzysztofi	MOLSI_057	USNM	1132671	Bransfield Strait	HM196673.1
Staurocucumis	krzysztofi	MOLSI_048	USNM	1132667	South Shetlands	HM196674.1
Crucella	hystrix	MOLAF_0793	NHM	2010.118	Amundsen Sea	HM196710.1
Crucella	hystrix	MOLN_170	NIWA	38641	Ross Sea	HM196711.1
Crucella	hystrix	MOLN_169	NIWA	42202	Ross Sea	HM196712.1
Crucella	hystrix	MOLN_171	NIWA	37784	Ross Sea	HM196713.1
Paracucumis	turricata	MOLAF_0791	NHM	2010.156	Amundsen Sea	HM196714.1
Paracucumis	turricata	MOLN_201	NIWA	36025	Ross Sea	HM196715.1
Paracucumis	turricata	MOLAF_0792	NHM	2010.157	Amundsen Sea	HM196716.1
Paracucumis	turricata	MOLN_200	NIWA	36490	Ross Sea	HM196717.1
Paracucumis	turricata	MOLN_202	NIWA	36007	Ross Sea	HM196718.1
Crucella	susannae	MOLSI_068	USNM	1132679	Bransfield Strait	HM196719.1
Crucella	scotiae	MOLG_098	NIWA	60742	Ross Sea	HM196720.1
Crucella	scotiae	MOLN_192	NIWA	36602	Ross Sea	HM196721.1
Crucella	scotiae	MOLG_097	NIWA	60730	Ross Sea	HM196722.1

Crucella	scotiae	MOLG_099	NIWA	60732	Ross Sea	HM196723.1
Psolidium	tenue	MOLAF_0709	NHM	2010.151	Amundsen Sea	HM196735.1
Abyssocucumis	abyssorum	MOLN_141a	NIWA	37727	Ross Sea	KP165441
Abyssocucumis	abyssorum	MOLN_141b	NIWA	37727	Ross Sea	KP165442
Abyssocucumis	abyssorum	MOLN_142	NIWA	38038	Ross Sea	KP165443
Abyssocucumis	abyssorum	MOLN_143	NIWA	38033	Ross Sea	KP165444
Cladodactyla	crocea	MOLAF_0501	NMV	F105017	Falkland Islands	KP165445
Cladodactyla	crocea	MOLAF_0502	NMV	F105017	Falkland Islands	KP165446
Cladodactyla	crocea	MOLAF_0503	NMV	F105002	Falkland Islands	KP165447
Cladodactyla	crocea	MOLAF_0504	NMV	F106967	Falkland Islands	KP165448
Cladodactyla	sicinski	MOLAF_1298	NMV	F193766	South Shetlands	KP165449
Cladodactyla	sicinski	MOLAF_1300	NMV	F193772	South Shetlands	KP165450
Crucella	hystrix	BASEC134-09	NHMUK	2010.118	Amundsen Sea	KP165451
Crucella	susannae	MOLAF_1293	NMV	F193784	South Shetlands	KP165452
Heterocucumis	denticulata	MOLG_101	NIWA	60822	Ross Sea	KP165453
Heterocucumis	denticulata	MOLG_102	NIWA	60824	Ross Sea	KP165454
Heterocucumis	denticulata	MOLG_103	NIWA	60794	Ross Sea	KP165455
Heterocucumis	denticulata	MOLG_104	NIWA	60784	Ross Sea	KP165456
Heterocucumis	denticulata	MOLG_105	NIWA	60799	Ross Sea	KP165457
Heterocucumis	denticulata	MOLN_163	NIWA	42174	Ross Sea	KP165458
Heterocucumis	denticulata	MOLN_164	NIWA	35932	Ross Sea	KP165459
Heterocucumis	steineni	BASEC079-09	NHMUK	2010.124	Amundsen Sea	KP165462
Heterocucumis	steineni	MOLAF_0874	NMV	F169300	South Orkneys	KP165461
Heterocucumis	steineni	MOLAF_1243	AAD BRC	525	Prydz Bay	KP165460
Laevocnus	katrinae	MOLAF_0815	NMV	F168836	Falkland Islands	KP165463
Laevocnus	laevigatus	MOLAF_0670	NMV	F165738	Heard Island	KP165464
Laevocnus	laevigatus	NDMQ_11	NIWA	40109	Macquarie Seamount	KP165465
Laevocnus	laevigatus	NDMQ_12	NIWA	40205	Macquarie Seamount	KP165466
Laevocnus	leachmani	MOLN_182	NIWA	42203	Ross Sea	KP165467
Laevocnus	leoninus	MOLAF_0507	NMV	F104820	Falkland Islands	KP165468
Laevocnus	leoninus	MOLAF_0508	NMV	F106960	Falkland Islands	KP165469
Laevocnus	leoninus	MOLAF_0509	NMV	F106962	Falkland Islands	KP165470
Laevocnus	leoninus	MOLAF_0510	NMV	F161500	Falkland Islands	KP165471
Laevocnus	perrieri	MOLAF_0511	NMV	F106964	Falkland Islands	KP165472
Laevocnus	perrieri	MOLAF_0512	NMV	F104844	Falkland Islands	KP165473
Laevocnus	perrieri	MOLAF_0514	NMV	F104844	Falkland Islands	KP165474
Laevocnus	serratus	MOLAF_0683	NMV	F165742	Heard Island	KP165475
Paracucumis	turricata	BASEC120-09	NHMUK	2010.157	Amundsen Sea	KP165477
Paracucumis	turricata	MOLAF_0891	NMV	F169314	South Orkneys	KP165476
Staurocucumis	krzysztofi	MOLSI_064	USNM	1132676	Bransfield Strait	KP165478
Staurocucumis	liouvillei	MOLAF_1247	AAD BRC	512	Prydz Bay	KP165479
Staurocucumis	liouvillei	MOLAF_1248	AAD BRC	513	Prydz Bay	KP165480
Staurocucumis	liouvillei	MOLAF_1249	AAD BRC	524	Prydz Bay	KP165481
Staurocucumis	nocturna	MOLAF_0399	NMV	F149749	NW Australia	KP165482
Staurocucumis	nocturna	MOLAF_0400	NMV	F151833	NW Australia	KP165483
Staurocucumis	species	MOLAF_0872	NMV	F169307	South Orkneys	KP165484
Staurocucumis	turqueti	MOLG_055	NIWA	61055	Ross Sea	KP165485
Staurocucumis	turqueti	MOLN_198	NIWA	35782	Ross Sea	KP165486
Staurocucumis	turqueti	MOLN_199	NIWA	42169	Ross Sea	KP165487

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A late Miocene record of the echinoid *Maretia* (Echinoidea, Spatangoida) from Victoria, Australia.

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Abstract Holmes, F.C. 2014. A late Miocene record of the echinoid *Maretia* (Echinoidea, Spatangoida) from Victoria, Australia. *Memoirs of Museum Victoria* 72: 63–72.

An unlabelled group of irregular echinoids, donated to Museum Victoria, are identified as *Maretia* sp. aff. *planulata* (Lamarck, 1816) and their place of origin determined as the late Miocene Tambo River Formation at Swan Reach, East Gippsland. A comparison with the three extant species of the genus, *M. planulata* (Lamarck, 1816), *M. carinata* Bolau, 1873, and *M.*? *cordata* Mortensen, 1948, show *Maretia* sp. aff. *planulata* has a fair degree of similarity with the type species *M. planulata*. Because of this, and the lack of detail of certain diagnostic features on the specimens, the description has been left in open nomenclature. The fossil record of *Maretia*, currently considered to occur only within the Indo-Pacific region, is also listed and discussed.

Keywords Echinoidea, Spatangoida, *Maretia*, late Miocene, Australia.

Introduction

While searching through a large collection of invertebrate fossils donated to Museum Victoria by F. A. Cudmore between 1924 and 1950, an unlabelled box of irregular echinoids was noticed amongst material from the Glenelg River area of Western Victoria. The colour and composition of the attached matrix on the echinoids, as well as the type of preservation, immediately raised doubts as to their actual origin.

Examination of the specimens suggested that they belong to *Maretia*, a genus not previously recorded in the fossil record of Australia. Determining their place of origin thus rested on identification of the attached matrix, which contains small grains of glauconite. While this mineral is not uncommon in sediments containing fossil echinoids, its Australian presence in granular form is recorded from only one area, the Tambo River Formation in East Gippsland, Victoria.

A further search of the Cudmore Collection revealed a small assortment of fossils labelled as coming from Swan Reach, Victoria, the stratotype section for the above Tambo River Formation (fig.1). The matrix with these fossils, and a few fragments of associated echinoid tests, clearly matched the unlabelled specimens. Further support for the origin of the echinoids was provided by the presence in each group of fossils of a specimen of the brachiopod *Frenulina pumila* (Tate, 1899), the type locality of which is Swan Reach (Richardson, 1973).

Materials and methods

The specimens are housed in the Invertebrate Palaeontology Collection, Museum Victoria (NMV). Where meaningful measurements where possible they were made with a dial calliper to an accuracy of 0.1 mm. Parameters are expressed as a percentage of test length (%TL).

Age and stratigraphy

The Tambo River Formation is late Miocene (Mitchellian, Tortonian-Messinian) in age, lying within International planktonic foraminiferal zones N16-N17. The section of the formation at Swan Reach, from which the specimens of *Maretia* are believed to have come, consists of six metres of fine orange-brown fine marly limestone containing numerous small grains of glauconite, with scattered bivalves and burrowed horizons occurring between discontinuous nodular cemented horizons. The presence of abundant bolivinids and other infaunal elements as well as the marly nature of the unit suggest a low energy palaeoenvironment, the coastal areas of the Formation representing transitional beds between the underlying middle Miocene Bairnsdale Limestone and the overlying late Miocene-Pliocene Jemmys Point Formation (Gallager and Holdgate, 1996, and papers cited therein). Strontium isotope dating of shells near the top of the Swan Reach road cutting have returned dates of 6.0 Ma (Dickinson, 2002).

Associated Fauna

Apart from the specimens of *Maretia* sp. aff. *planulata*, the only echinoids recorded from the Tambo River Formation are spines of *Goniocidaris murrayensis* Chapman and Cudmore, 1934, and *Phylacanthus clarki clarki* (Chapman and Cudmore, 1934); the latter identified by Crespin (1943) as *Phylacanthus duncani* Chapman and Cudmore, 1934.

The rarity of echinoids is unusual, considering the presumed low energy depositional environment of the formation and the abundance of *Clypeaster gippslandicus* M^{c}Coy, 1879, in the underlying Bairnsdale Limestone and of *Fellaster insisa* (Tate, 1893) in the overlying Jemmys Point Formation. However, the lack of any previous record of echinoids, other than spines, may simply be due to the paucity of surface exposures.

Systematic palaeontology

Order **Spatangoida** L. Agassiz, 1840

Family **Maretiidae** Lambert, 1905

Remarks. According to Smith and Kroh (2011) the family includes fourteen genera, three of them assigned with question: *Araeolampas*?, *Eupatagus, Granobrissoides, Gymnopatagus, Hemimaretia, Homolampas, Maretia, Mariania*?, *Mazettia, Murraypneustes, Nacospatangus, Pycnolampas, Spatagobrissus* and *Tripatagus*?

Excluding the reference to *Eupatagus*, which is now referred to the family Eupatagidae Lambert, 1905 (Kroh, 2014a), *Maretia* differs from other genera in the family by a combination of four primary features: lack of a peripetalous fasciole, sternal plates with small tubercules only in the posterior half, four gonopores, and the absence of a prominent sulcus.

Genus ***Maretia*** Gray, 1855

Type species. *Spatangus planulata* Lamarck, 1816, by original designation.

Other species (listed by Smith and Kroh, 2011). *Maretia carinata* Bolau, 1873, *M.*? *cordata* Mortensen, 1948, *M.*? *tuberculata* Agassiz and Clark, 1907, *M.* sp. of Henderson (1975), *M.*? *subrostrata* (Clark, 1915), and *M.*? *aequipetala* (Gregory, 1891).

Diagnosis. (Modified from Smith and Kroh, 2011). Test moderate in size, ovate tapering posteriorly, with or without slight anterior depression, weakly arched to depressed in profile, oral surface flat except for low posterior keel; ambitus low and moderately sharp. Apical disk slightly anterior of centre, ethmolytic with 4 gonopores, genital plate 2 projecting far to the posterior of posterior oculars. Anterior ambulacrum narrow and flush adapically, pore-pairs small, isopores simple. Other ambulacra petaloid and flush. Anterior paired petals bowed, with adapical pore-pairs in anterior column rudimentary; remainder large and semi-conjugate. Posterior petals bowed to lanceolate, converging distally. Periproct on short steeply undercut truncate face; peristome wider than long, kidney-shaped, with adoral ambulacra forming a distinct phyllode. Labral plate narrow and elongate, just contacting sternal plates adjacent to the posterior half of adjoining third ambulacral plates; paired sternal plates narrow and triangular with tuberculation confined to the posterior. Aboral tuberculation heterogenous, with scattered sunken primary tubercules on interambulacra 1-4 varying markedly in density and generally missing in interambulacrum 5. On oral surface lateral tubercles arranged in distinct rows with slightly sunken areoles and spiral parapet. Subanal fasciole shield shaped, and generally well developed.

Remarks. According to Mortensen (1951: 26), in the previous 100 or so years no less than 40 fossil species, ranging in age from Eocene to Recent, have been assigned to *Maretia* or *Hemipatagus*; the two at times being considered synonymous. Most of the confusion in separating the two genera has been rectified by Kroh (2007) who listed species of *Hemipatagus*, *Maretia,* and presumed related spatangoids, accompanied by details of synonymy, type species and locality, and occurrence and age. Based on this information and cladistic analysis of specimens, the suggested taxonomic placement of these species was discussed in detail.

However, the seven species of *Maretia* listed by Smith and Kroh (2011) include four assigned to the genus with question: *M.*? *cordata*, because of it's prominent cordate outline and distinct anterior sulcus; *M.*? *tuberculata,* considered a juvenile specimen possibly assignable to *Lovenia*; *M.*? *subrostrata*, a species containing many features in common with *Hemipatagus*; and *M.*? *aequipetala*, because the type material is too poorly preserved for a positive identification. Of the remaining three species, even the illustrations of *M.* sp. from New Zealand suggest it is most likely related to *M.*? *cordata.*

Maretia sp. aff. ***planulata*** (Lamarck, 1816)

Figures 2A-F, 3A-H, Table 1

Material. Specimens NMV P324331–P324338 from the stratotype locality of the late Miocene Tambo River Formation (Mitchellian, Tortonian-Messinian) at Swan Reach, Victoria [NMV locality PL3110]. A quantity of disarticulated plates together with a sample of matrix found with these specimens are numbered NMV P322439.

Description. Test ovate to sub-pentagonal tapering to a semi-truncated posterior margin, slightly flattened adjacent to anterior depression, and weakly arched adapically with apex approximately central; margins rounded. Interambulacrum 5 mildly raised on the aboral surface at the interradial suture, and on the adoral surface swollen to form a posterior keel. Length of specimens range from 50-55 mm with width varying from 78-88%TL. Apical system showing 4 gonopores partially preserved on only one specimen (fig.3A); no detail of plate structure or hydropores can be discerned. Centre of apical disk 40-43.5%TL from anterior ambitus.

Anterior ambulacrum III, narrow and flush aborally, slightly depressed at ambitus and on adoral surface; no detail of pores. Anterior paired petals quite indistinct and possibly rudimentary but, based on ambulacrual plate suture, appear flush, straight sided, narrow and with maximum width only 3/5 that of posterior pair; detail of pores and tuberculation too poorly preserved to describe. Posterior paired petals,

Table 1. Comparison of diagnostic features of the late Miocene *Maretia* sp. aff. *planulata* (Lamarck, 1816) from Swan Reach, Victoria, with the extant *Maretia planulata* (Lamarck, 1815), based on specimens from the Philippines, and *M. carinata* Bolau, 1873, and *M. cordata* Mortensen, 1948, based on descriptions in Mortensen (1951) and Schultz (2005 and 2009).

Diagnostic feature	***Maretia planulata*** (Lamarck)	***Maretia carinata*** Bolau	***Maretia cordata*** Mortensen	***Maretia* sp. aff. *planulata*** (Lamarck)
Test shape	Ovate, with or without slight anterior depression, flattened or low arched adapically. Plaston and adjacent anbulacra form distinct keel posteriorly. Margin rather sharp.	Ovate with mere trace of anterior depression, high arched with posterior surface of interamb. 5 raised to form prominent keel on aboral surface. Margin rounded.	Generally smaller, broader and distinctly cordate. Anterior depression wider and deeper. Adapical surface low arched.	Basically ovate with moderate anterior depression, low arched adapically, both aboral and adoral surface of interamb. 5 swollen posteriorly. Margin more rounded.
Width as % test length	Av. 82.7%TL (based on 3 extant specimens).	Approx 85%TL (based on published figures).	Over 90%TL (based on published figures).	Approx 85%TL (based on 4 specimens).
Apical system	Approx. 40%TL from anterior ambitus, ethmolytic, with 4 gonopores and genital plate 2 extending to rear of oculars 4 and 5.	Approx. 38.5% TL from anterior ambitus, otherwise as for *M. planulata* (generic feature)	Approx. 43.5% TL from anterior ambitus, otherwise as for *M. planulata* (generic feature)	Approx. 41.5%TL from anterior ambitus. Only partially preserved on one specimen which appears to shows 4 gonopores.
Anterior ambulacrum	Narrow, flush, or slightly depressed at anterior ambitus. Pore pairs small to rudimentary in single longitudinal column.	No specific information	Plates longer and fewer than *M. planulata* and sunken towards frontal depression.	Appears as for *M. planulata* based on what little preservation occurs on specimens.
Anterior paired petals	Straight, wide, lanceolate, distal end nearly closed. Rudimentary pore-pairs in anterior column adapically for about 1/3 length.	Well-formed, shorter, with corresponding reduction in number of pore-pairs compared to *M. planulata* of similar size.	Distinctly broader, pore-pairs fewer compared to M. planulata of similar size. In anterior column only 4 plates have rudimentary or no pore-pairs proximally.	Preservation very poor in all specimens, however they appear fairly rudimentary, much narrower, straight sided and more obtuse than *M. planulata.*
Posterior paired petals	Longer and broader than anterior pair, straight or slightly S-shaped,	Well-formed, shorter and broader than M. planulata.	More like *M. carinata* than *M.. planulata..*	Marginally shorter and not as broad as *M. planulata*
Petals generally	Inter pore zone wide, slightly raised and covered with varying sized tubercles. Pairs not strictly conjugate.	Similar to *M. planulata.*	Inter pore zone not raised and sculpture between pore-pairs more elaborate than in *M. planulata.*	Pore zones contain more miliary granules; otherwise similar to *M. planulata.*
Periproct	Longer than wide with both ends distinctly pointed, situated in mildly concave, short, steeply undercut face.	Posterior face only mildly undercut and slightly concave. More like *M. cordata* than *M. planulata..*	About as long as wide and nearly round. Posterior margin rounded not undercut.	Not well preserved on any specimen but appears to be similar to *M. planulata.*
Peristome	Reniform, wider than long and sunken, but only in relation to raised projecting labrum. Groups of small tubercules occur around the peristome at junction of interambs 1-4.	Published illustrations suggest projection of labrum not as prominent.	Not strictly reniform, more rounded pentagonal in shape, no projection of labrum.	Preservation poor but raised projecting labrum suggests similarity to *M. planulata.* Small tubercules at junction of interanb's and peristome also visible on most specimens.
Phyllodes	Reasonably well developed, lateral 8-10, anterior 6.	Less developed than *M. planulata*	Longer and broader than *M. planulata.*	Poorly preserved - most plates missing or weathered.

Diagnostic feature	***Maretia planulata*** (Lamarck)	***Maretia carinata*** Bolau	***Maretia cordata*** Mortensen	***Maretia* sp. aff. *planulata*** (Lamarck)
Labrum	Narrow, very elongated, contacting sternal plates near posterior end of adjacent 3rd ambulacral plates. Anterior edge forms prominent lip above peristome,	Relatively broad, extending just posterior to centre of adjoining 3rd ambulacral plates. Anterior edge slightly curved at junction with peristome.	Narrower, marginally broader mid length. No projection at junction with peristome; otherwise similar to *M. planulata*.	Similar to *M. planulata*..
Sternal plates	Paired, long, narrow and triangular. Posterior 35-45% covered with small tubercles.	Paired but broader and conspicuously raised compared with *M. planulata*.	Paired, shorter & wider than *M. planulata*.	Similar to *M. planulata*.
Episternal plates	Tuberculated and sharply undercut by marked increase in width of plate 6 of adjoining ambulacra.	As *M. planulata* (familial feature)	As *M. planulata* (familial feature)	Assumed similar, but not clearly defined due to cracking across plates.
Subanal fasciole	Outline reniform, continuous below periproct, rising adorally over ambulacral plates 6-9 and across episternals.	Details of subanal fasciole do not appear to have been recorded.	Generally well developed but recorded as sometimes rather indistinct, posterior side straight, not re-entrant.	Extent indeterminate due to poor preservation of test. Only two specimens show a small section of fasciole, one of which is re-entrant.
Primary tubercules	Perforate, crenulate, areoles moderately sunken, heterogeneous on aboral surface except on interamb. 5 which has only a few small tubercles. Margin, including plates adjacent periproct, covered with closely spaced small tubercules increasing in size adorally in interambs 1 & 4 to form radiating rows of very closely spaced primaries with ear shaped areoles.	Primary aboral tubercules somewhat less numerous than in *M. planulata* specimens of similar size .Tubercules on aboral surface of interambulacrum 5 fairly large but not considered primary.	Primary aboral tubercules similar in density to *M. planulata* specimens of similar size but in larger specimens interamb. 5 contains a number of large tubercles.	Generally as for *M. planulata* but with primary aboral tubercules on interambs 1 & 4 somewhat less numerous (as in *M. carinata*) and with some large tubercles in interamb. 5 of size similar to those in interambs 1-4. Adoral primary tubercles considerably more widely spaced.

lanceolate, closing distally, wider and longer than anterior pair, pores eye shaped, outer and inner appear to be similar in size, not strictly conjugate but each side of plate sutures between pairs angularly sunken. Interporiferous zone covered with randomly placed small tubercles and numerous miliary granules, the latter extending across the pore zones (fig. 2F).

Periproct longer than wide situated on steep undercut truncate face, exact shape indistinct. Peristome also poorly preserved in all specimens but clearly wider than long with convex anterior lip of labrum overhanging posterior side. Phyllodes and groups of small tubercules at termination of interambulacra with peristome partially visible on some specimens (fig. 3B).

Labrum narrow and very elongate, just contacting sternal plates adjacent posterior end of adjoining third ambulacral plates, and with a number of small tubercles on anterior lip, similar to those at end of adoral interambulcra (fig. 3D,E). Sternal plates paired, long, narrow and triangular, extending to posterior end of adjoining fifth ambulacral plates. The posterior ends of the plates are covered with small tubercles for 40-45% of their length and possess a ventral apex at the centre just anterior of the posterior sutures (fig. 2E). Episternal plates, covered with small tubercles, are probably triangular and undercut by re-entrant sixth ambulacral plates; junction with sub-anal plates indeterminate. Due to extensive posterior damage, the subanal fasciole is partially visible on only two specimens; a small indistinct section crossing the episternal plates (fig. 3G), and a re-entrant section adjoining the periproct (fig. 3H).

Heterogeneous, moderately spaced, perforate and crenulate, primary tubercles with sunken areoles as well as occasional small tubercles occur on the aboral surface of interambulacra 1-4 (fig. 3C). Several small tubercles and a few primaries, the latter generally towards the posterior ambitus, occur on interambulacrum 5. Small closely spaced tubercules immediately below the ambitus in ambulacra 1-4 increase in

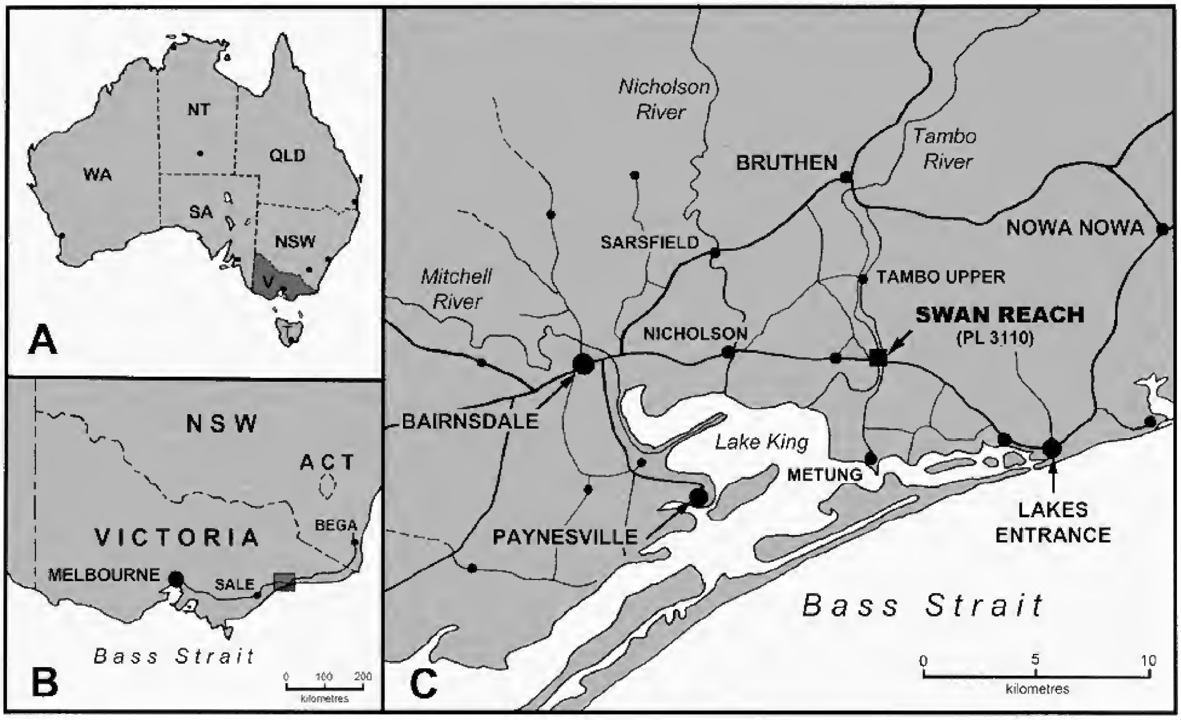

Figure 1. A, B, general location maps; C, map of East Gippsland, Victoria, from Bairnsdale to Lakes Entrance, showing locality NMV PL3110 at Swan Reach.

size but reduce in quantity adorally to form distinct radiating rows of primary tubercles. Plates surrounding the periproct are also covered with small tubercles.

Remarks. All specimens are to some degree deformed, often incomplete, with some of the plates cracked and their sutures opened up. Nevertheless it is possible to compare individual features of the specimens with those of the three extant species of *Maretia*: *M. planulata, M. carinata, and M.? cordata* (Table 1).

Apart from primary generic characteristics present in all four species compared in the table, approximately 70 percent of the listed diagnostic features are common to both *M.* sp. aff. *planulata* and the type species *M. planulata*. Comparison with *M. carinata* is more difficult to summarise as two important diagnostic features that distinguish it from *M. planulata*, the number of pore pairs in paired petals and the development of the phyllodes, are not preserved in the fossil specimens. Excluding the generic characteristics and these latter features, *M.* sp. aff. *planulata* has only about 30 percent of its diagnostic characteristics in common with *M. carinata*. Similarity between *M.* sp. aff. *planulata* and *M.? cordata* is quite minimal.

In descriptions of *Maretia* species, the density of tubercles on parts of the test has been used as a diagnostic feature; particularly the density of primary tubercles on aboral interambulacra 1-4. However, based on the extant specimen from the Philippines (fig. 2G) and numerous published photographs of *M. planulata* (e.g. Mortensen, 1951; Fisher, 1966; Schultz, 2005; Kroh, 2007; Smith and Kroh, 2011), there appears to be considerable variation in density and arrangement of these tubercles, making comparison of this feature between species of the genus, somewhat tenuous.

Fossil record of *Maretia*

Extant species of *Maretia*, principally *M. planulata*, are currently considered to occur in two distinct Indo-Pacific marine zones:

1. East Africa, from Mozambique north to Egypt and Saudi Arabia on the Red Sea; and the western Indian Ocean Islands, particularly Madagascar, Mauritius and the Seychelles.

2. From southern India and Sri Lanka, eastwards across the Indo-Malayan Archipelago, Indonesia, the Philippines, Papua New Guinea, north and east Australia, and the western Pacific Islands from Japan in the north to Fiji and New Caledonia in the south, and as far east as Hawaii.

The fossil record of species, currently assigned to the genus, is consistent with the present-day distribution of extant forms, with one exception, but is restricted to less than a dozen specific localities (fig.4).

East Africa. *M. ovata* (Leske, 1778) from three localities in the Pliocene Zanzibar Series, Zanzibar (Unguja) Island,

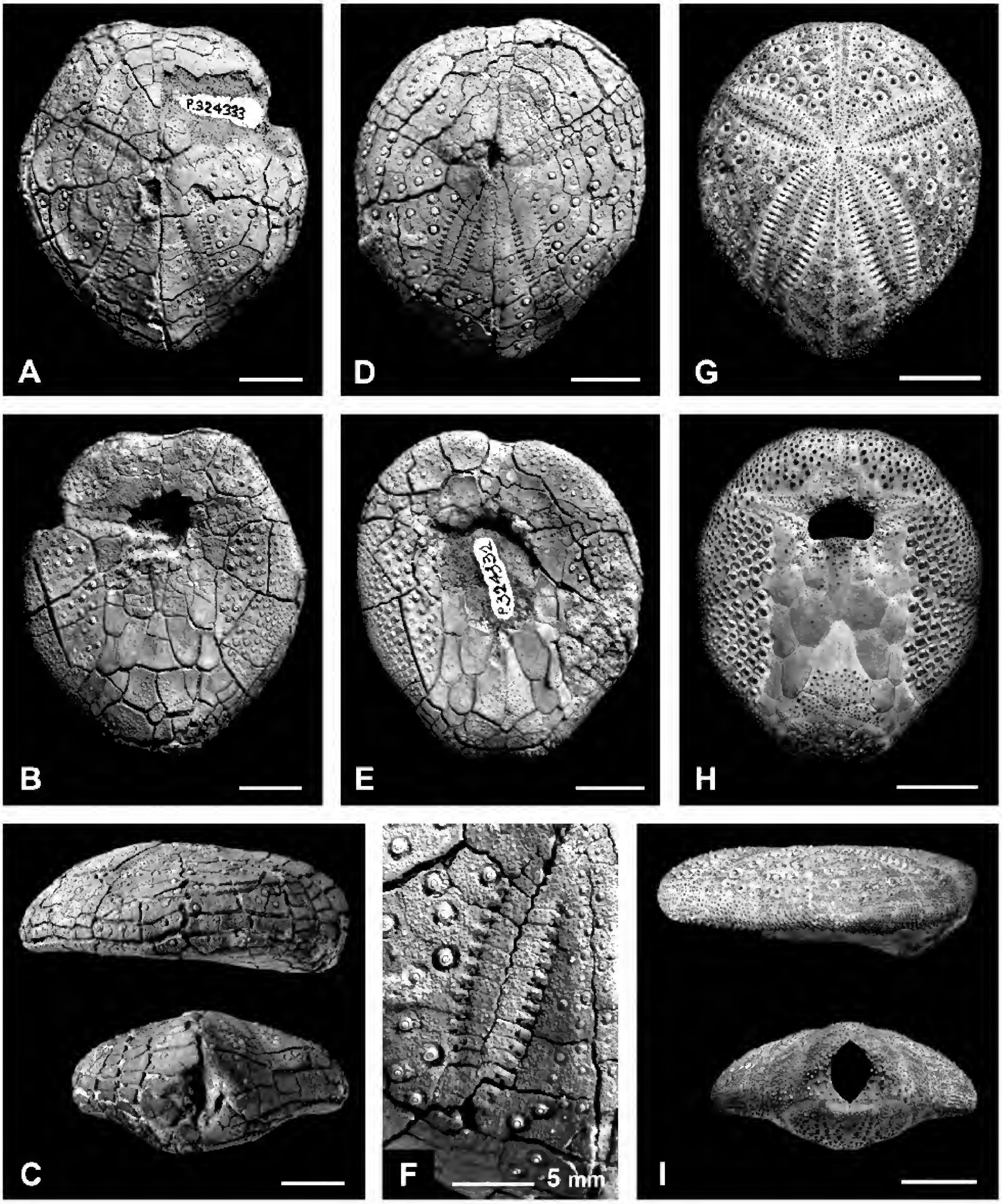

Figure 2. *Maretia* sp. aff. *planulata* (Lamarck, 1816): A-C, adapical, adoral, left lateral and posterior views of NMV P324333; D, E, adapical and adoral views, and F, aboral ambulacrum V detail of NMV P324332, both specimens from the late Miocene, Tambo River Formation, Swan Reach, Victoria. G-I, adapical, adoral, left lateral and posterior views of extant specimen of *Maretia planulata* from the Philippines. Scale bar 10 mm unless otherwise stated.

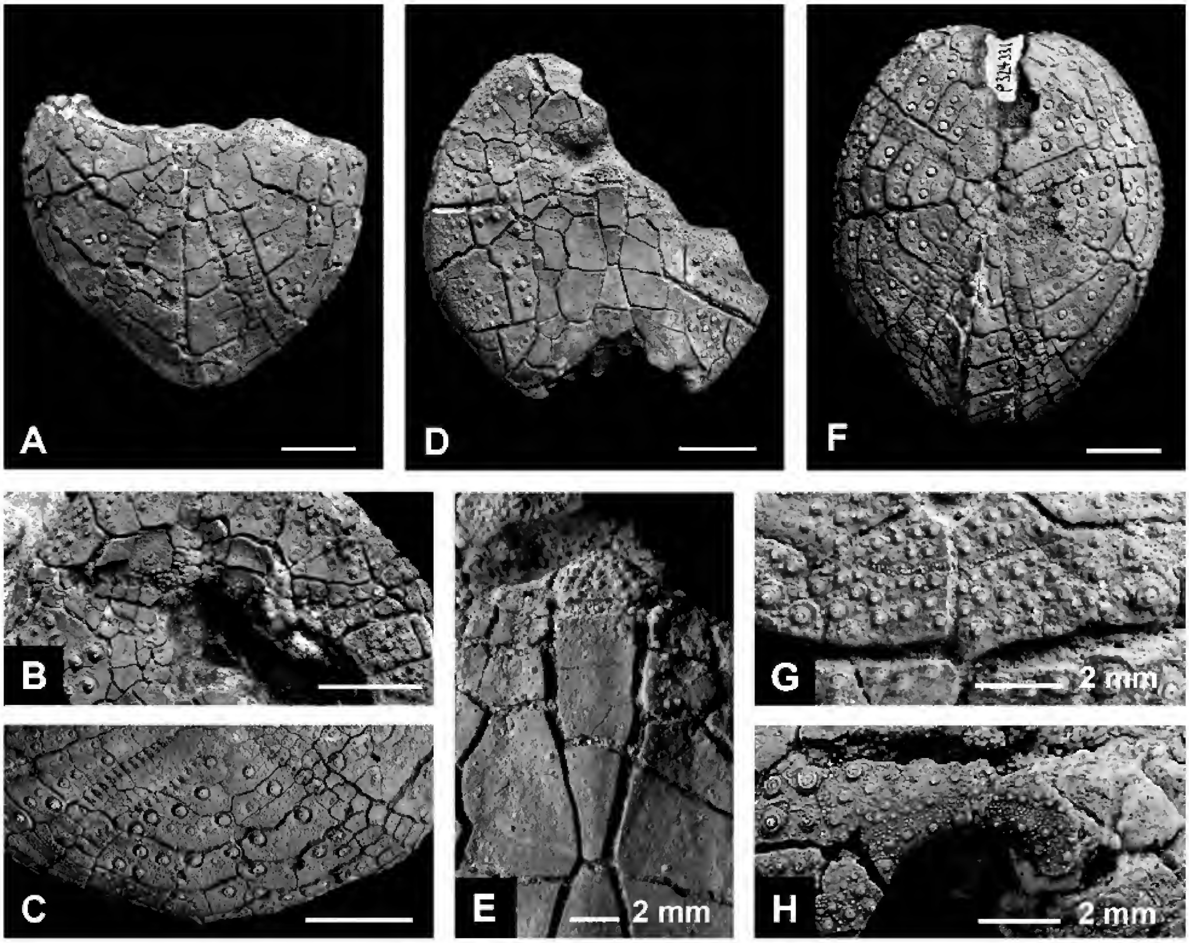

Figure 3. *Maretia* sp. aff. *planulata* (Lamarck, 1816): A, adapical view of NMV P324337 recording presence of four gonopores; B, partial adoral view of NMV P324338 showing phyllodes and small tubercules at termination of interambulacra with peristome; C, partial adapical view of NMV P324332 showing interambulacra 1 and ambulacrun I and II; D, E, adoral view and labrum detail of NMV P324336; F, adapical view of NMV P324331; G, partial adoral view of NMV P324332 showing an indistinct section of subanal fasciole crossing episternal plates; H, partial posterior view of NMV P324333 with re-entrant section of subanal fasciole adjoining the periproct. Specimens from the late Miocene, Tambo River Formation, Swan Reach, Victoria. Scale bar 10 mm unless otherwise stated.

Tanzania (Stockley, 1927: 117). However, Eames and Kent (1955: 342) revised the age of these Pliocene deposits to early Miocene, and in a footnote state "Comparison, in the British Museum Natural History, of the Zanzibar Lower Miocene *Clypeaster*, *Maretia* and temnopleurids with recent material indicates that they are not attributable to the species to which they have been assigned." The Tanzanian fossil specimens of *Maretia* assigned to the taxon *M. ovata* (Leske) by Stockley, is almost certainly the result of *Spatangus planulatus* Lamarck, 1816, being synonymised with *Spatangus ovatus* Leske, 1778 (H.L.Clark 1917: 248 and 1925: 226). Mortensen (1951: 37) recounts in considerable detail the history of this synonymy, clearly stating that there is no real foundation for any change; the figures and description of *Spatangus ovatus* being poor and of unknown affinity. The taxon is now cited in the World Register of Marine Species (Kroh, 2014b) as *Maretia ovata* H.L.Clark, 1917; a subjective junior synonym of *M. planulata* (Lamark, 1816).

Red Sea. *M. ovata* (Leske) from four localities in the Pliocene basal beds of the Marly Limestone Series, Farsan Islands, Saudi Arabia (Brighton, 1931: 332). In referring to the specimens as *M. ovata* (Leske), Brighton appears to have followed the synonymy in Stockley (1927) without question.

Red Sea. *M. planulata abbassi*, Ali, 1985: 294, a new subspecies from the lower Pliocene of Wadi Abu Abraiki, Egypt, based primarily on differences in the aboral ambulacra. However, no reference was made to the sternal plates having a distinct contact with adjoining ambulacral plates 6a and 6b, as

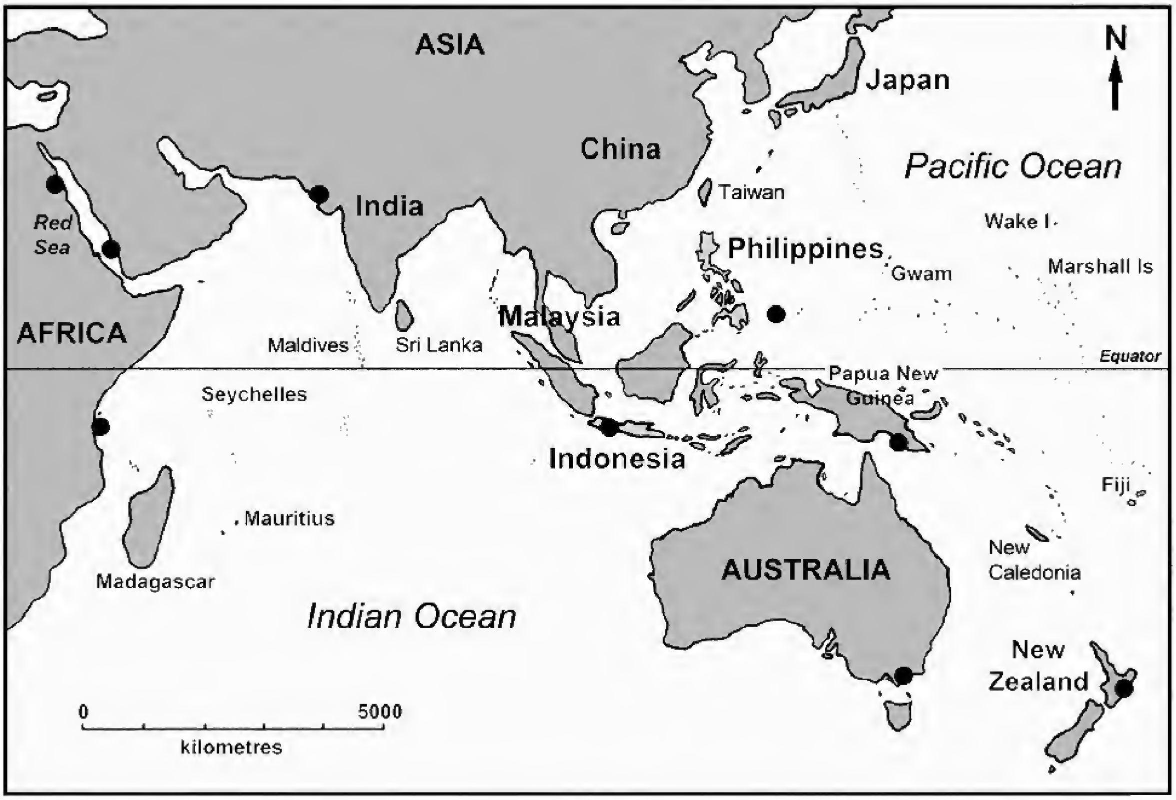

Figure 4. Generalised map of the Indo-Pacific Region showing localities where fossil specimens attributable to *Maretia* have been found (•).

shown on the oral view of the holotype. This feature is unusual, as contact of these latter plates is normally with the episternals. As only the holotype is recorded, it is not possible to determine if this feature is simply an anomaly.

India. *M. ranjitpurensis* Jain, 2002: 130, a questionable species from the Raj Formation (? Burdigalian), Kathiawar, Gajarat, western India. Described from eight specimens, it differs from *M planulata* only in the far smaller number of aboral primary tubercles and the wider angle of the anterior paired ambulacra. It appears to be the first record of the genus, either fossil or extant, from the area that separates the two distinct marine zones referred to above; the State of Gajarat bordering Pakistan.

Indonesia. *Spatangus praelongus* Herklots, 1854: 11, a species from the Miocene of Tjidamar, western Java. Subsequent authors considered this species synonymous with *M. planulata* and of Pliocene age (Mortensen 1951: 37).

Papua New Guinea. *M. planulata* (Lamarck, 1816), a partial test from the lower Pliocene Kairuku Formation, Yule Island, Central Province (Lindley, 2003: 160). Also recorded were two specimens of *M. cordata* from the same general location.

South Sea Islands. *M. planulata* (Lamarck, 1816), a single internal mould from the Pleistocene Younger Angaur Limestone of Angaur Island, Palao Island Group, Micronesia (Nisiyama, 1968: 205).

New Zealand. *Maretia* sp. of Henderson (1975: 33). Two partially preserved specimens from the upper Miocene (Kapitean) of Tawhiti Hill, north Tokomaru Bay, east coast of North Island.

United Kingdom. *Agassizia aequipetala* Gregory, 1891: 39, from the Pliocene Coralline Crag, Aldborough, Suffolk. Although this has been tentatively assigned to *Maretia* (Sullivan, 2007), it's origin, and the information on which this identification was made are considered inadequate for it to be included in the currently accepted distribution of both fossil and extant species of *Maretia*.

The earliest occurrence of *Maretia*, considered to be in the Pliocene (Kroh, 2007: 173), needs to be revised to take account of the late Miocene record of *M.* sp. aff. *planulata* from the Tambo River Formation. However, the early to middle Miocene age given for the Indian specimens from the Raj Formation and the revision of the age of the Zanzibar Series specimens from Pliocene to early Miocene, if correct, would extend the known range of the genus further back in time by several million years.

Because of poor preservation and general lack of detail in many of the above fossils, and the possibility that there may be differences in both fossil and extant populations of *M. planulata* between the two distinct marine zones in the Indo-Pacific region, description of the specimens from the Tambo River Formation has been left in open nomenclature. Features common to both *M. planulata* and *M. carinata* (Table 1) are those most likely to be preserved in older fossil specimens, often making specific identification problematical. Currently, extant specimens of both of these species are found from the Indo-Malayan Archipelago to the western Pacific Islands, and include the north Queensland coast of Australia (Cannon et al., 1987).

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Australian Dragonfly (Odonata) Larvae: Descriptive history and identification

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Abstract Theischinger, G. and Endersby, I. 2014. Australian Dragonfly (Odonata) Larvae: Descriptive history and identification. *Memoirs of the Museum of Victoria* XX: 73-120.

To improve the reliability of identification for Australian larval Odonata, morphological and geographic information is summarised for all species. All known references that contain information on characters useful for identification of larvae are presented in an annotated checklist. For polytypic genera information is provided to clarify whether each species can already, or cannot yet, be distinguished on morphological characters, and whether and under which conditions geographic locality is sufficient to make a diagnosis. For each species the year of original description and of first description of the larva, level of confidence in current identifications, and supportive information, are included in tabular form. Habitus illustrations of generally final instar larvae or exuviae for more than 70% of the Australian dragonfly genera are presented.

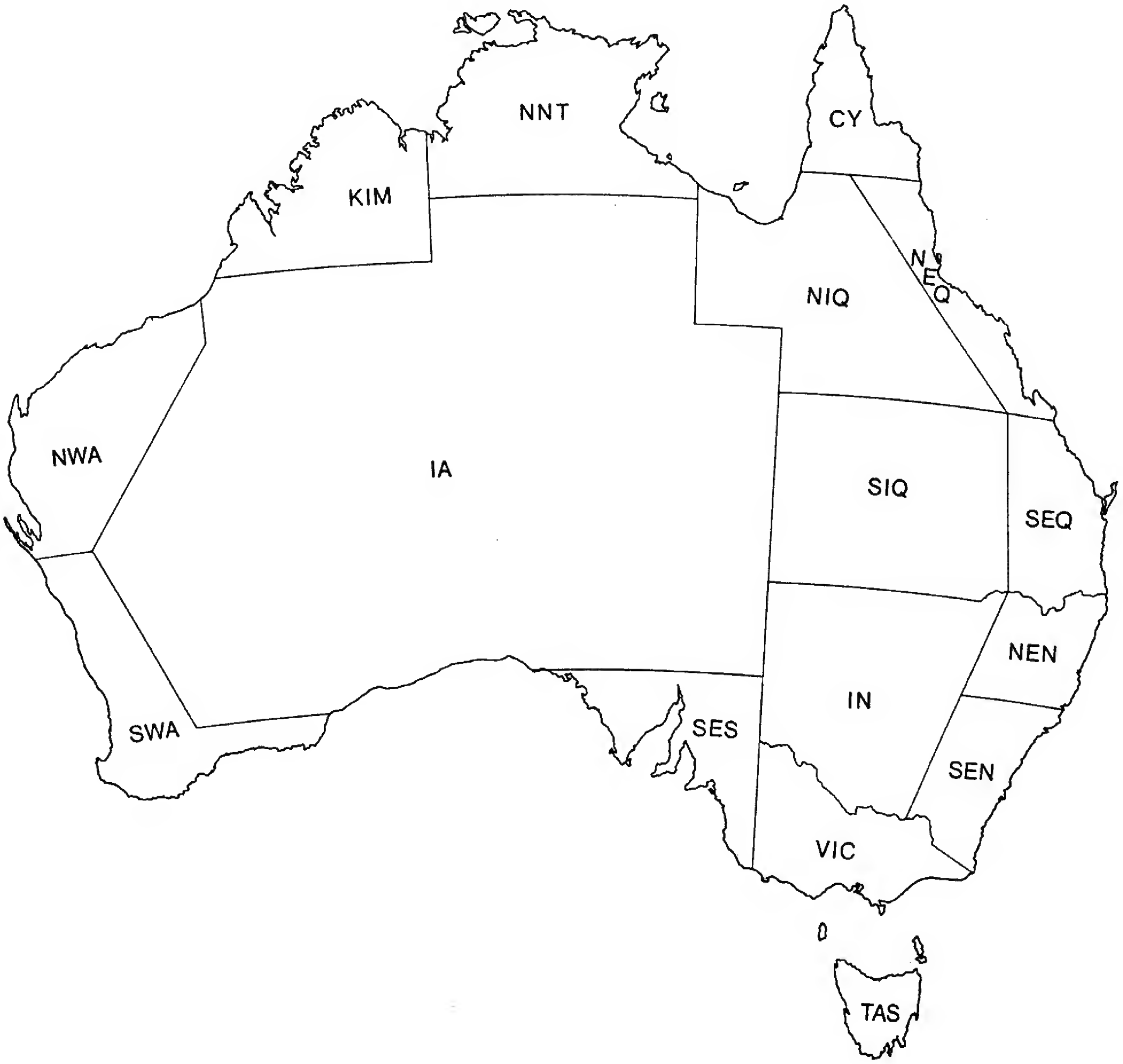
Keywords Odonata, Australia, larvae, descriptive history, identification

Introduction

The size, colour, tremendous flight abilities and unusual reproductive behaviours of dragonflies make them one of the most attractive and conspicuous orders of insects. Larval dragonflies are aquatic and usually associated with clean water making them useful biological indicators of water quality. Thus information on the presence, abundance, diversity and reproductive ability are in high demand for assessments and modelling connected with river health, biodiversity, conservation, climate change and other environmental issues. Although flying adults are generally more likely to be encountered specific habitat data from larvae, which are confined to freshwater environments, provides extremely valuable and inclusive information on the health of aquatic ecosystems. For at least 20 years numerous nation- and state-wide, as well as regional monitoring programs have incorporated dragonfly larvae, amongst other macroinvertebrates, in their aquatic sampling protocols.

Unfortunately, while adult dragonflies can usually be reliably identified from a number of national and regional field guides and keys (e.g. Watson et al. (1993), Theischinger & Hawking (2006), Theischinger & Endersby (2009)), the situation is quite different for larvae. Although a wealth of information useful for identification of Australian odonate larvae is available, it is currently scattered throughout the literature, often in rather obscure journals. The descriptive literature on dragonfly larvae ranges from brief descriptions or line drawings of single structures in single species to comprehensive revisions (including colour photos and keys) of large taxonomic groups. The most comprehensive treatments come from Tillyard (1916a, 1926), Watson (1962), Theischinger (1982, 1998d, 2000b, 2001a, 2002, 2007a), Theischinger & Watson (1984), Hawking (1986, 1993), Hawking & Theischinger (1999) and Theischinger and Endersby (2009). However, morphological characters of larvae are more variable within single species and therefore less diagnostic than those of adults. They can also change significantly with development from early to late instars, and sometimes with habitat conditions. In addition, keys are usually constructed only for final instars and require more or less perfect and complete specimens, and some characters included in descriptions and keys have proved less consistent than originally envisaged. In monitoring programs early instar larvae are much more frequently collected than final instars. As well, the fragile larvae of zygopteran species often lose body parts during the collection process. Reliable specific identifications are rarely possible when diagnostic morphological characters are not available or when sympatric congeneric species have undescribed larvae. And even for parts of a geographic range where a species is supposedly the only member of its genus or species group, there is always a chance that we have underestimated the geographical range of other closely related species.

We have more than forty years of experience with the identification of Australian dragonfly larvae (including checking identifications in many voucher collections) and must emphasize the importance of considering the above variables when making identifications. Therefore we feel it is necessary to complement the basic descriptive information on known Australian dragonfly larvae by providing a realistic view of achieving accurate species identifications. It must be stressed here that it is the final instar (larva or exuvia) that is referred to in the literature, and that distribution-based identifications need to be treated with some caution. However the known geographical ranges of species should not be neglected when making identifications because greater reliability in identification is possible by finding larval exuviae in association with adults and by having the best possible knowledge of the regional fauna where the specimens are found.



Map 1. The regions of Australia referred to in text and table (from Watson *et al.* (1991). SWA = south-western Australia; SES = south-eastern South Australia; VIC = Victoria; TAS = Tasmania; SEN = south-eastern New South Wales; NEN = north-eastern New South Wales; SEQ = south-eastern Queensland; NEQ = north-eastern Queensland; CY = Cape York Peninsula; NNT = top end of Northern Territory; KIM = Kimberley region; NWA = north-western Australia; IN = inland New South Wales; SIQ = southern inland Queensland; NIQ = northern inland Queensland; IA = inland Australia.

Methods

All known species of Australian dragonflies are listed following the family order of the World Systematic Consensus of Dijkstra *et al.* (2013) (with the additions of Kalkman & Theischinger (2013)), and all references that include descriptive details and/or illustrations/photos of larvae are given in chronological order, not in the order of usefulness for identifications. The reliability/difficulty of generic identifications is indicated under the family headings. Following the species of each polytypic genus/subgenus (marked with an asterisk *) a brief summary is presented of the potential for reliable specific identification. Line drawings (Figs 1-81) and colour photographs (Figs 82-94) of at least one species per family are presented followed by a table giving references for descriptive information, the basis for reliable identification of each species, the present state of knowledge and the level of confidence for species identification. We construct and present a graph that shows the chronological growth of specific descriptive information on Australian dragonfly larvae, and a summary of all information included in the paper is given. Maps 1 and 2 are taken from Watson *et al.* (1991) and Watson & Theischinger (1984), and distributional details are based on the dot maps in Theischinger & Endersby (2009) and additional unpublished information.

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Descriptive literature on the larvae of Australian dragonfly species, with remarks on species identification within polytypic genera

Order Odonata

Two suborders, clearly distinguishable on morphology (Theischinger & Hawking 2006; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Suborder **Zygoptera**

Eight families, clearly distinguishable on morphology (Theischinger & Hawking 2006; Theischinger & Endersby 2009; Hawking *et al.* 2013).

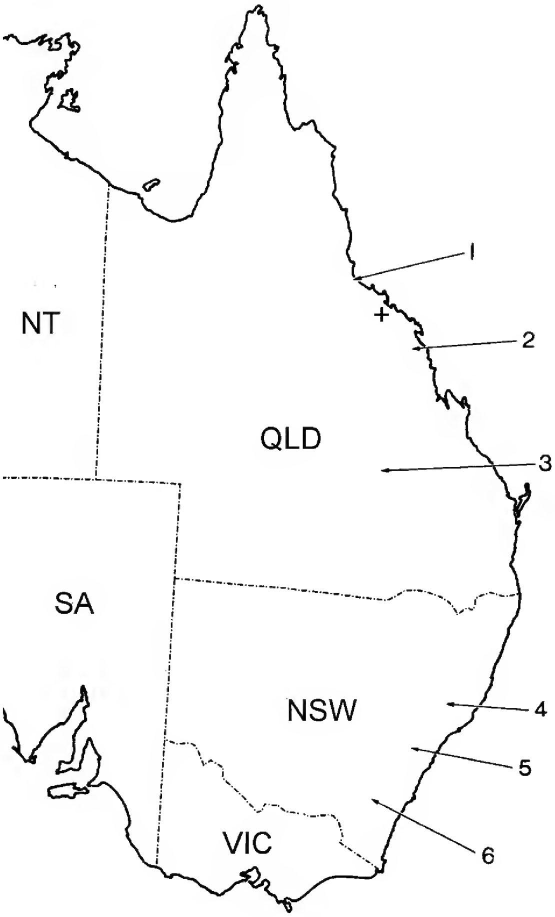
Family **Hemiphlebiidae**

Monotypic family, distinguishable on morphology (Theischinger & Hawking 2006; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Hemiphlebia mirabilis Selys, 1869

Fig. 1

Tillyard (1928); Hawking (1995); Williams (1980); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.



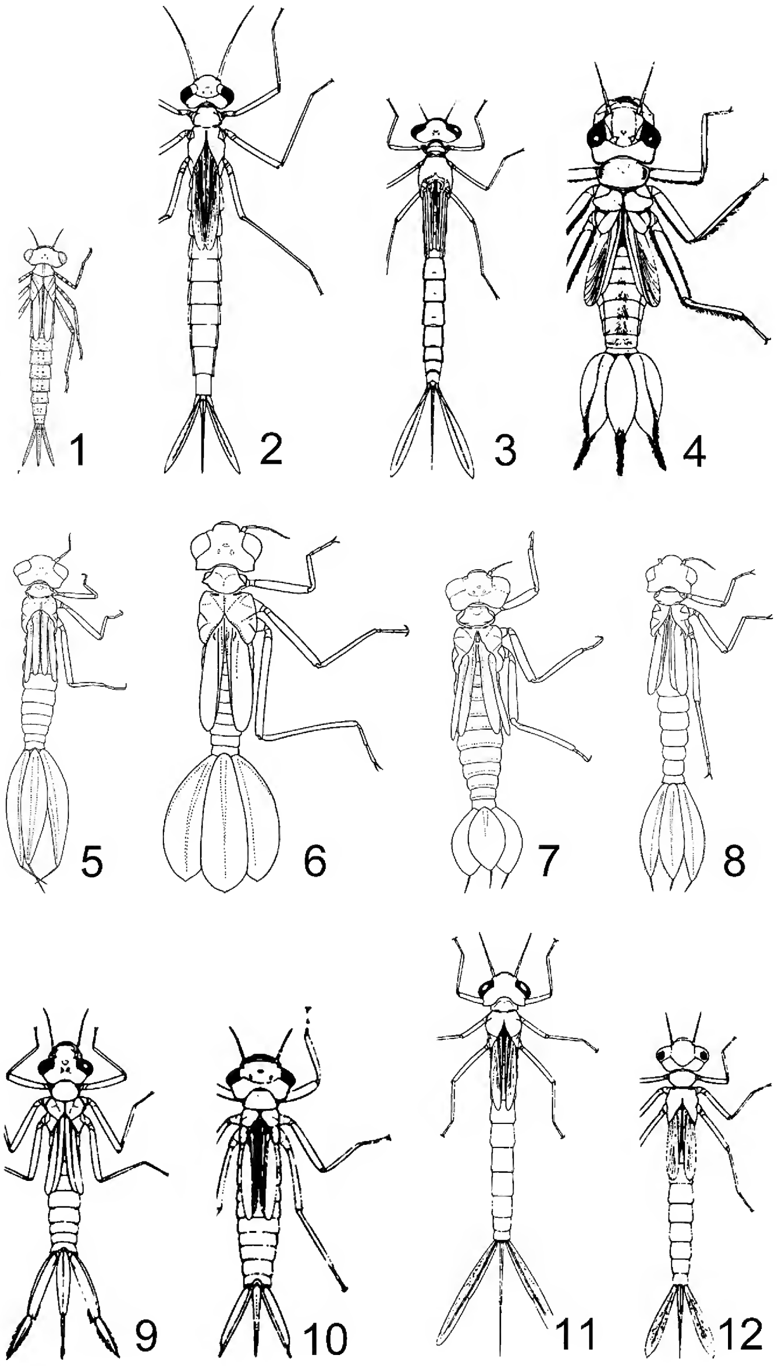
Map 2. Map of eastern Australia showing relevant localities (from Watson & Theischinger (1984). NSW = New South Wales; NT = Northern Territory; QLD = Queensland; SA = South Australia; VIC = Victoria; 1 = Paluma Range; 2 = Eungella; 3 = Carnarvon Gorge; 4 = Barrington Tops; 5 = Blue Mountains; 6 = Canberra. The Paluma-Eungella gap (marked with +, ca. 19°S) spans between 1 and 2.

Family **Synlestidae**

Three genera clearly distinguishable on morphology (Theischinger & Hawking 2006; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Chorismagrion risi Morton, 1914

Fraser (1956); Theischinger *et al.* (1993); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.



Figs 1-12. Final instar larvae of Australian Zygoptera: (1) *Hemiphlebia mirabilis* (Hemiphlebiidae); (2) *Synlestes weyersii* (Synlestidae); (3) *Austrolestes annulosus* (Lestidae); (4) *Diphlebia euphoeoides* (Lestoideidae); (5-8) Argiolestidae: (5) *Archiargiolestes parvulus*; (6) *Austroargiolestes icteromelas*; (7) *Griseargiolestes griseus*; (8) *Miniargiolestes minimus*; (9) *Austrosticta soror* (Isostictidae); (10) *Nososticta pilbara* (Platycnemididae); (11, 12) Coenagrionidae: (11) *Caliagrion billinghursti*; (12) *Ischnura heterosticta*.

Episynlestes albicauda (Tillyard, 1913)

Theischinger *et al.* (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Episynlestes cristatus Watson & Moulds, 1977

Fraser (1956), as *Synlestes tropicus*; Theischinger *et al.* (1993); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Episynlestes intermedius Theischinger & Watson, 1985

Theischinger *et al.* (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus ***Episynlestes*** Kennedy, 1920

Specific identifications based on morphology need confirmation by distributions (Theischinger *et al.* 1993). North of Paluma-Eungella gap: *E.cristatus*; Eungella area: *E. intermedius*; south of Paluma-Eungella gap: *E. albicauda*.

Synlestes selysi Tillyard, 1917

Theischinger *et al.* (1993); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Synlestes tropicus Tillyard, 1917

Theischinger *et al.* (1993); Theischinger & Hawking (2006); Theischinger & Endersby (2009); The description of *S. tropicus* by Fraser (1956) refers to *Episynlestes cristatus*.

Synlestes weyersii Selys, 1869

Figs 2, 82

Tillyard (1914, 1917a, 1917b, 1926); O'Farrell (1970); Williams (1980), as *S. tillyardi*; Nuttall (1982); Hawking (1986, 1995); Watson & O'Farrell (1991); Watson *et al.* (1991); Theischinger *et al.* (1993); Hawking & Theischinger (1999); Gooderham & Tsyrlin (2002); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Synlestes*** Selys, 1869

At present specific identifications based on morphology need confirmation by distributions (Theischinger *et al.* 1993). North of Paluma-Eungella gap: *S. tropicus*; from Eungella area south to approximately 36°S: *S. selysi/weyersii*; south of approximately 36°S: *Synlestes weyersii*.

Family **Lestidae**

Three genera clearly distinguishable on morphology (Theischinger & Hawking 2006; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Austrolestes aleison Watson & Moulds, 1979

Watson (1962), as *A. psyche*; Watson *et al.* (1991); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austrolestes analis (Rambur, 1842)

Tillyard (1906, 1917b, 1932); Ris (1910), as larva B; Lieftinck (1960); Watson (1962); O'Farrell (1970); Allbrook (1979); Williams (1980); Nuttall (1982); Hawking (1986); Watson & O'Farrell (1991); Hawking & Theischinger (1999); Gooderham & Tsyrlin (2002); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Austrolestes annulosus (Selys, 1862)

Fig. 3

Ris (1910), as larva A; Lieftinck (1960); Watson (1962); O'Farrell (1970); Allbrook (1979); Nuttall (1982); Hawking (1986); Watson & O'Farrell (1991, 1994); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Austrolestes aridus (Tillyard, 1908)

Lieftinck (1960); Watson (1962); Nuttall (1982); Hawking (1986); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Austrolestes cingulatus (Burmeister, 1839)

Tillyard (1906, 1914, 1917a, 1917b, 1926); Allbrook (1979); Nuttall (1982); Hawking (1986, 1995); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Austrolestes insularis Tillyard, 1913

Larva not yet recognized.

Austrolestes io (Selys, 1862)

Lieftinck (1960); Watson (1962); Allbrook (1979); Nuttall (1982); Hawking (1986); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Austrolestes leda (Selys, 1862)

Tillyard (1906, 1917a); Watson (1962); Allbrook (1979); Hawking (1986, 1995); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Austrolestes minjerriba Watson, 1979

Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austrolestes psyche (Hagen, 1862)

Tillyard (1917a, 1717b); Lieftinck (1960); Allbrook (1979); Nuttall (1982); Hawking (1986, 1995); Hawking & Theischinger (1999); Gooderham & Tsyrlin (2002); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009). Watson (1962) has to be referred to *Austrolestes aleison*.

*Genus ***Austrolestes*** Tillyard, 1913

Morphology based identifications need geographical confirmation for two species: South-western Australia: *A. aleison*; south-eastern Australia: *A. psyche*. *A. insularis* (larva still undescribed) should be the only species across most of northern Australia (Theischinger & Endersby 2009).

Indolestes alleni (Tillyard, 1913)

Larva not yet recognized.

Indolestes obiri Watson, 1979

Larva not yet recognized.

Indolestes tenuissimus (Tillyard, 1906)

Lieftinck (1960); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Indolestes*** Fraser, 1922

Morphology based identifications of *Indolestes* from north-eastern Queensland may include both *I. tenuissimus* and *I. alleni,* those from the north of Northern Territory *I. alleni* and *I. obiri* (Theischinger & Endersby 2009).

Lestes concinnus Hagen, 1862

Lieftinck (1960); Hawking (1993); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013), as *Lestes*. Sole species of the genus in Australia.

Family **Lestoideidae**

Two genera clearly distinguishable on morphology and size (Theischinger & Hawking 2006, Theischinger & Endersby 2009, both under Diphlebiidae and Lestoideidae; Hawking *et al.* 2013).

Lestoidea barbarae Watson, 1967

Larva probably not available

Lestoidea brevicauda Theischinger, 1996

Larva not identifiable at the present.

Lestoidea conjuncta Tillyard, 1913

Fraser (1956); Hawking (1995); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Larva not identifiable at present.

Lestoidea lewisiana Theischinger, 1996

Larva not yet recognized.

*Genus ***Lestoidea*** Tillyard, 1913

The available descriptions by Fraser (1956); Theischinger & Hawking (2006) and Theischinger & Endersby (2009) enable firm identification of *Lestoidea* sp. only. *L. lewisiana* may be endemic to, and the only *Lestoidea* species in, the Mt Lewis area.

Diphlebia coerulescens Tillyard, 1913

Stewart (1980); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Diphlebia euphoeoides Tillyard, 1907

Fig. 4

Stewart (1980); Watson & O'Farrell (1991); Watson *et al.* (1991); Hawking (1995); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Diphlebia hybridoides Tillyard, 1912

Stewart (1980); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Diphlebia lestoides (Selys, 1853)

Tillyard (1909b, 1912, 1915a, 1917b, 1926); Stewart (1980); Williams (1980); Hawking (1986); Hawking & Smith (1997); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Diphlebia nymphoides Tillyard, 1912

Tillyard (1912); Stewart (1980); Hawking (1986); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus ***Diphlebia*** Selys, 1869

On the basis of the available information on morphology (Stewart 1980) confident identifications were hitherto found impossible. *D. euphoeoides* and *D. hybridoides* are known only from north of the Paluma-Eungella gap; *D. coerulescens* from the Eungella area south to approximately 30°S, whereas both *D. lestoides* and *D. nymphoides* seem to inhabit only eastern Australia south of 24°S, but with only *D. nymphoides* inhabiting Carnarvon N.P. (Theischinger & Endersby 2009).

Family **Argiolestidae**

Five genera clearly distinguishable on morphology (Theischinger & Hawking 2006, Theischinger & Endersby 2009, both under Megapodagrionidae; Hawking *et al.* 2013).

Archiargiolestes parvulus (Watson, 1977)

Fig. 5

Theischinger (1998b). Hawking *et al.* (2013), as *Archiargiolestes*.
Larva not identifiable at present.

Archiargiolestes pusillissimus Kennedy, 1925

Theischinger (1998b).
Larva not identifiable at present.

Archiargiolestes pusillus (Tillyard, 1908)

Watson (1962). Theischinger (1998b).
Larva not identifiable at present.

*Genus ***Archiargiolestes*** Kennedy, 1925

Even though larval details of all three species are available specific identifications are not possible at the present (Theischinger & Endersby 2009).

Austroargiolestes alpinus (Tillyard, 1913)

Larva not yet recognized.

Austroargiolestes amabilis (Förster, 1899)

Larva not yet recognized.

Austroargiolestes aureus (Tillyard, 1906)

Larva not identifiable at present.

Austroargiolestes brookhousei Theischinger & O'Farrell, 1986

Larva not yet recognized.

Austroargiolestes calcaris (Fraser, 1958)

Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Larva not identifiable at present.

Austroargiolestes christine Theischinger & O'Farrell, 1986

Larva not yet recognized.

Austroargiolestes chrysoides (Tillyard, 1913)

Larva not identifiable at present.

Austroargiolestes elke Theischinger & O'Farrell, 1986

Larva not yet recognized.

Austroargiolestes icteromelas (Selys, 1862)

Fig. 6

Tillyard (1917a, 1917b, 1926, 1932); O'Farrell (1970), all as *Argiolestes icteromelas*; Lieftinck (1976), Nuttall (1982), as *Austroargiolestes* sp. 1; Hawking (1986, 1995); Watson & O'Farrell (1991, 1994); Watson *et al.* (1991); Hawking & Smith (1997); Theischinger (1998b); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).
Larva not identifiable at present.

Austroargiolestes isabellae Theischinger & O'Farrell, 1986

Murray (1995); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).
Larva not identifiable at present.

*Genus ***Austroargiolestes*** Kennedy, 1925

With *A. icteromelas* potentially coexisting with any other of its extremely similar congeners, generally the only confident identification appears to be *Austroargiolestes* sp. (Theischinger & Endersby 2009) even though most of the usually collected larvae belong to *A. icteromelas*.

Griseargiolestes albescens (Tillyard, 1913)

Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Griseargiolestes bucki Theischinger, 1998

Theischinger (1998c); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Griseargiolestes eboracus (Tillyard, 1913)

Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Griseargiolestes fontanus (Tillyard, 1913)

Larva not yet recognized.

Griseargiolestes griseus (Hagen, 1862)

Fig. 7

Tillyard (1914, 1917a), Hawking (1986), both as *Argiolestes griseus*; (Theischinger 1998b); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Griseargiolestes intermedius (Tillyard, 1913)

Fig. 83

Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Griseargiolestes metallicus (Sjöstedt, 1917)

Larva not yet recognized.

*Genus **Griseargiolestes** Theischinger, 1998

It should be easy to identify the larva of *G. metallicus* once it is found as it is the only *Griseargiolestes* species known from north of the Paluma-Eungella gap. The larva of *G. fontanus* is expected to be found most likely near springs of subtropical rainforest streams. Distributions may be needed to establish/confirm the identification of *G. griseus* and *G. intermedius* with only *G. intermedius* present in the alpine region and *G. griseus* mostly north and east of it (Theischinger & Endersby 2009).

Miniargiolestes minimus (Tillyard, 1908)

Fig. 8

Watson (1962), Hawking (1995), both as *Argiolestes minimus*; Theischinger (1998b); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Podopteryx selysi (Förster, 1899)

Watson & Dyce (1978); Hawking (1995); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of the genus in Australia.

Family **Isostictidae**

Eight genera clearly distinguishable on morphology (Theischinger & Hawking 2006; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Austrosticta fieldi Tillyard, 1908

Hawking (1993); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austrosticta frater Theischinger, 1997

Larva not yet recognized.

Austrosticta soror Sjöstedt, 1917

Fig. 9

Watson & O'Farrell (1991); Watson *et al.* (1991).

*Genus **Austrosticta** Tillyard, 1908

Because of the possible sympatric existence of the three species, larvae of this genus without associated imago can only be identified as *Austrosticta* sp. (Theischinger & Endersby 2009).

Eurysticta coolawanyah Watson, 1969

Watson (1969); Watson *et al.* (1991); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Eurysticta coomalie Watson, 1991

Hawking (1993); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Eurysticta kununurra Watson, 1991

Hawking (1993, 1995); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Eurysticta reevesi Theischinger, 2001

Larva not yet recognized.

*Genus **Eurysticta** Watson, 1969

It appears that the known larvae of this genus can be identified to species in spite of the possible sympatric existence of *E. coomalie* and *E. kununurra* (Theischinger & Endersby 2009).

Labidiosticta vallisi (Fraser, 1955)

Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Lithosticta macra Watson, 1991

Hawking (1993, 1995); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Neosticta canescens Tillyard, 1913

Tillyard (1914, 1917a, 1917b); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Neosticta fraseri Watson, 1991

Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Neosticta silvarum (Sjöstedt, 1917)

Larva not yet recognized.

*Genus **Neosticta** Tillyard, 1913

Based on distributions, larvae from south-eastern Australia can be identified as *N. canescens*, whereas *Neosticta* larvae from north of the Paluma-Eungella gap may be the common *N. fraseri* or the more local and uncommon *N. silvarum* (Theischinger & Endersby (2009).

Oristicta filicicola Tillyard, 1913

Fraser (1956); Williams (1980); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Rhadinosticta banksi (Tillyard, 1913)

Hawking (1993), as *Rhadinosticta handschini*; Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Rhadinosticta simplex (Martin, 1901)

Tillyard (1914, 1917a, 1917b, 1926); Hawking (1986), all as *Isosticta simplex*; Hawking (1995); Hawking & Smith (1997); Hawking & Theischinger (1999); Gooderham & Tsyrlin (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Rhadinosticta*** Watson, 1991

A good generic character is the presence of 6 dark spots on the otherwise pale labium. The two species are identifiable based on morphology. Larvae from south-eastern Australia can be confirmed by distribution as *R. simplex* (Theischinger & Endersby (2009).

Selysioneura sp.

Theischinger (2009). Sole species of the genus in Australia. It appears that only one and as yet undescribed *Selysioneura* species exists in tropical Queensland.

Family **Platycnemididae**

A single genus clearly distinguishable on morphology (Theischinger & Hawking 2006, under Protoneuridae; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Nososticta baroalba Watson & Theischinger, 1984

Larva not yet recognized.

Nososticta coelestina (Tillyard, 1906)

Larva not yet recognized.

Nososticta fraterna (Lieftinck, 1933)

Hawking (1993); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Nososticta kalumburu Watson & Theischinger, 1984

Larva not yet recognized.

Nososticta koolpinyah Watson & Theischinger, 1984

Larva not yet recognized.

Nososticta koongarra Watson & Theischinger, 1984

Hawking (1993); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Nososticta liveringa Watson & Theischinger, 1984

Larva not yet recognized.

Nososticta mouldsi Theischinger, 2000

Larva not yet recognized.

Nososticta pilbara Watson, 1969

Fig. 10

Watson (1969), as *Nososticta solida pilbara*; Watson & O'Farrell (1991); Watson *et al.* (1991); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Nososticta solida (Hagen, 1860)

Nuttall (1982), as Protoneuridae sp.; Hawking (1986, 1995); Hawking & Theischinger (1999); Gooderham & Tsyrlin (2002); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Nososticta solitaria (Tillyard, 1906)

Larva not yet recognized.

Nososticta taracumbi Watson & Theischinger, 1984

Larva not yet recognized.

*Genus ***Nososticta*** Hagen in Selys, 1860

Because of the sympatric existence of two or more species across much of northern Australia and rather weak characters, *Nososticta* larvae cannot be identified to the species at present except for larvae from New South Wales and Victoria that can be referred to *N. solida*, the sole *Nososticta* species occurring there (Theischinger & Endersby (2009).

Family **Coenagrionidae**

13 genera distinguishable on morphology, two of them, *Austroagrion* and *Xanthagrion*, difficult (see there), larva of *Archibasis* unknown (Theischinger & Hawking 2006; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Aciagrion fragile (Tillyard, 1906)

Hawking (1993); Theischinger (2000a); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of the genus in Australia.

Agriocnemis argentea Tillyard, 1906

Larva not yet recognized.

Agriocnemis dobsoni Fraser, 1954

Larva not yet recognized.

Agriocnemis femina (Brauer, 1868)

Lieftinck (1962).

Agriocnemis kunjina Watson, 1969

Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Agriocnemis pygmaea (Rambur, 1842)

Allbroook (1979); Nuttall (1982); Hawking (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Agriocnemis rubricauda Tillyard, 1913

Larva not yet recognized.

*Genus ***Agriocnemis*** Selys, 1877

With the larvae of most species still undescribed, and the available larvae having few diagnostic characters, the only reliable specific identifications possible at present are *A. femina* with its range in Australia restricted to Cape York and *A. pygmaea* if collected in New South Wales (Theischinger & Endersby 2009).

Archibasis mimetes (Tillyard, 1913)

Larva not yet recognized. Sole species of the genus in Australia.

Argiocnemis rubescens Selys, 1877

Tillyard (1917a, 1917b), Hawking (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of the genus in Australia.

Austroagrion cyane (Selys, 1876)

Watson (1962), as *Austroagrion coeruleum*; Hawking (1986). The reference to *A. cyane* by Allbrook (1979) refers to *A. watsoni*.

Austroagrion exclamationis Campion, 1915

Hawking (1993); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austroagrion pindrina Watson, 1969

Larva not yet recognized.

Austroagrion watsoni Lieftinck, 1982

Tillyard (1917a), Allbrook (1979), Nuttall (1982), all as *Austroagrion cyane*; Hawking (1986, 1993); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Austroagrion*** Tillyard, 1913

The larva of *A. exclamationis* can confidently be identified. Based on morphology larvae from south-western Australia and South Australia can confidently be referred to *A. cyane*, larvae from south-eastern Australia to *A. watsoni*, and larvae from the Pilbara area in north-western Australia to *A. pindrina* (Theischinger & Endersby 2009). However, there is an overlap of *A. cyane* and *A. watsoni* in the extreme west of Victoria (Richter 2014). The diagnostic characters of *Austroagrion* (from *Xanthagrion erythroneurum*) of the median caudal gill seem to work only for final instar larvae. More distinctly ringed antennae and a narrower labium usually distinguish younger *Austroagrion* larvae from *Xanthagrion*.

Austrocnemis maccullochi (Tillyard, 1926)

Hawking (1993); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austrocnemis obscura Theischinger & Watson, 1991

Larva not yet recognized.

Austrocnemis splendida (Martin, 1901)

Tillyard (1917a); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Austrocnemis*** Tillyard, 1913

The larvae of *A. maccullochi* can confidently be identified based on morphology, of the remaining larvae those from eastern Australia can confidently be referred to *A. splendida*, those from the Kimberley to *A. obscura* (Theischinger & Endersby 2009).

Austrocoenagrion lyelli (Tillyard, 1913)

Allbrook (1979), where it appears that the caudal gill is described upside down; Nuttall (1982); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013); all under *Coenagrion lyelli*. Genus monotypic.

Caliagrion billinghursti (Martin, 1901)

Fig. 11

Tillyard (1914, 1917a, 1917b, 1926); O'Farrell (1970); Williams (1980); Nuttall (1982), Hawking (1986, 1995); Watson & O'Farrell (1991); Watson *et al.* (1991); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009). Genus monotypic.

Ceriagrion aeruginosum (Brauer, 1869)

Lieftinck (1936); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of the genus in Australia.

Ischnura aurora (Brauer, 1865)

Tillyard (1917b); Lieftinck (1962); Watson (1962); Allbrook (1979); Nuttall (1982); Hawking (1986, 1993, 1995); Hawking & Smith (1997); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Ischnura heterosticta (Burmeister, 1839) (Fig. 12)

Tillyard (1917a, 1917b), Watson (1962); O'Farrell (1970); Allbrook (1979); Nuttall (1982); Hawking (1986, 1993, 1995); Watson & O'Farrell (1991), Ingram *et al.* (1997); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Ischnura pruinescens (Tillyard, 1906)

Hawking (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus ***Ischnura*** Charpentier, 1840

Distributions do not confirm any identification based on morphology of the often sympatric species but size and morphology of final instars should be sufficient for reasonably confident identifications (Theischinger & Endersby 2009).

Pseudagrion aureofrons Tillyard, 1906

Hawking (1986, 1993, 1995); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Pseudagrion cingillum (Brauer, 1869)

Larva not yet recognized.

Pseudagrion ignifer Tillyard, 1906

Theischinger (2000a); Theischinger & Hawking (2006); Theischinger & Endersby (2009). Reference to this species by Hawking & Theischinger (1999) probably refers to *P. microcephalum.*

Pseudagrion jedda Watson & Theischinger, 1991

Larva not yet recognized.

Pseudagrion lucifer Theischinger, 1997

Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Pseudagrion microcephalum (Rambur, 1842)

Lieftinck (1962); Watson *et al.* (1991); Hawking (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus ***Pseudagrion*** Selys, 1876:

The known larvae of the Australian *Pseudagrion* species can be confidently distinguished from each other by the combination of morphological characters and distributions. However, only *P. aureofrons*, *P. microcephalum* and *P. ignifer* from eastern Australia south of about latitude Rockhampton can be confidently identified because *P. cingillum* and *P. jedda* coexist in the same areas as *P. aureofrons*, *P. ignifer*, *P. microcephalum* and *P. lucifer* in northern Australia (Theischinger & Endersby 2009) and their as yet undescribed larvae may be indistinguishable from one or two of them.

Teinobasis rufithorax (Selys, 1877)

Larva not yet recognized. Sole species of the genus in Australia.

Xanthagrion erythroneurum (Selys, 1876)

Fig. 84

Watson (1962); Allbrook (1979); Nuttall (1982); Hawking (1986,1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of the genus in Australia. The diagnostic characters (from *Austroagrion*) of the median caudal gill seem to work only for final instar larvae. Less distinctly ringed antennae and a wider labium usually distinguish younger *X. erythroneurum* larvae from *Austroagrion.*

Suborder **Anisoptera**

Eight families + one group of genera incertae sedis, clearly distinguishable on morphology (Theischinger & Hawking 2006, under Epiproctophora; Theischinger & Endersby 2009, under Epiprocta; Hawking *et al.* 2013).

Family **Austropetaliidae**

Two genera clearly distinguishable on morphology (Theischinger & Hawking 2006, under Archipetaliidae and Austropetaliidae; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Archipetalia auriculata Tillyard, 1917

Fig. 13

Albrook (1979); Gooderham & Tsyrlin (2002); Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Austropetalia annaliese Theischinger, 2013

Larva not yet recognized.

Austropetalia patricia (Tillyard, 1910)

Fig. 14

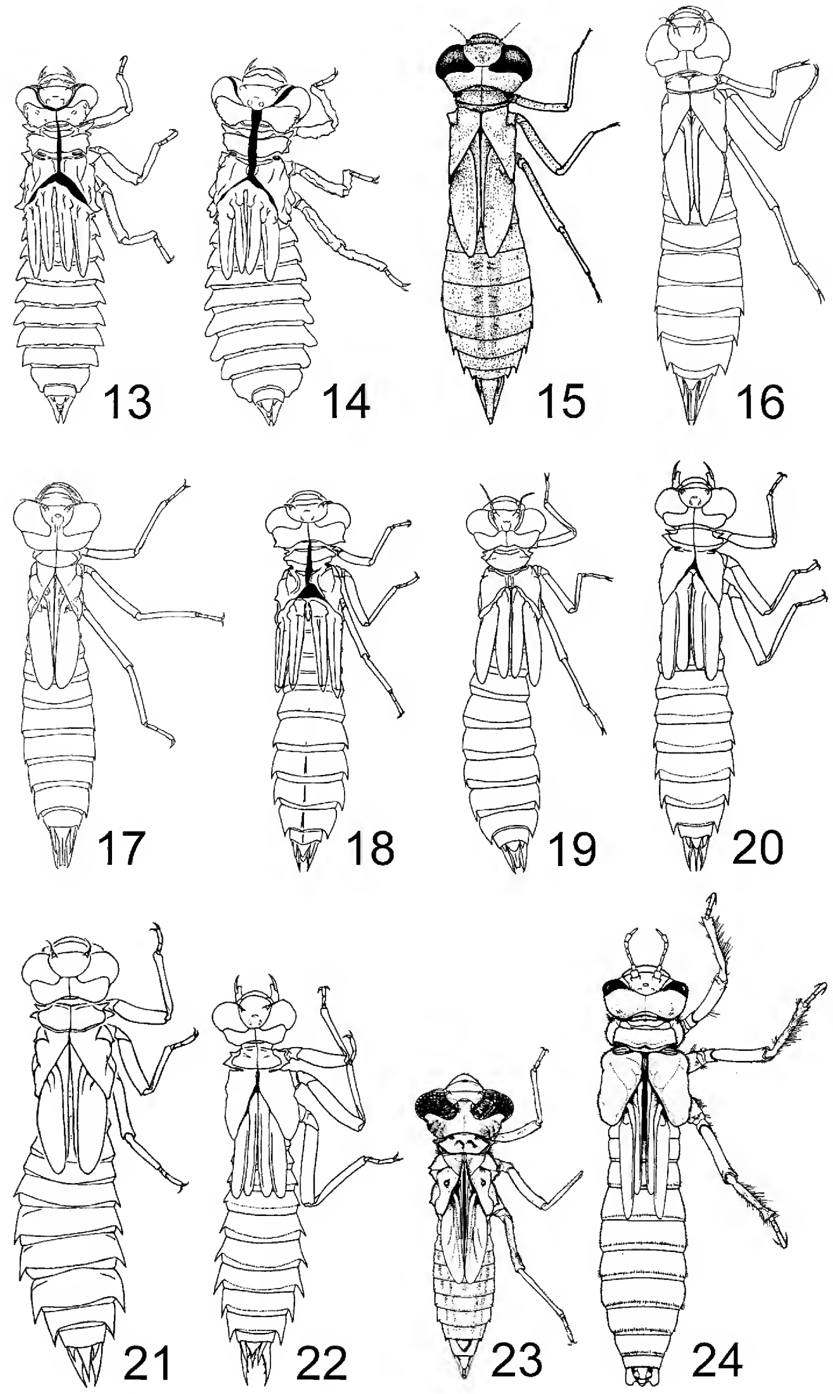
Tillyard (1910a, 1916a,1917b, 1926); Hawking (1986, 1995), has to be referred to *A. tonyana*; Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Theischinger & Tang (2012).

Austropetalia tonyana Theischinger, 1995

Hawking (1986, 1995), as *A. patricia;* Hawking & Smith (1997); Hawking & Theischinger (1999); Theischinger (2002); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Theischinger & Tang (2012); Hawking *et al.* (2013).

*Genus ***Austropetalia*** Tillyard, 1916

The easiest specific identification for *Austropetalia* larvae is by the probably exclusive distributions. North of the Hunter River: *A. annaliese* (larva as yet not available); south of the Hunter River to approximately 35°S: *A. patricia*; south of approximately 35°S: *A. tonyana* (Theischinger 2002; Theischinger & Endersby 2009; Theischinger & Tang 2013).



Figs 13-24. Final instar larvae/exuviae of Australian Anisoptera: (13, 14) Austropetaliidae: (13) *Archipetalia auriculata*; (14) *Austropetalia patricia*; (15-23) Aeshnidae: (15) *Adversaeschna brevistyla*; (16) *Anax gibbosulus*; (17) *Austrogynacantha heterogena*; (18) *Dendroaeschna conspersa*; (19) *Acanthaeschna victoria*; (20) *Austroaeschna (Pulchaeschna) muelleri*; (21) *Austrophlebia costalis*; (22) *Spinaeschna tripunctata*; (23) *Telephlebia brevicauda*; 24) *Petalura hesperia* (Petaluridae).

Family **Aeshnidae**

13 genera and several subgenera clearly distinguishable on morphology (Theischinger & Hawking 2006, under Aeshnidae and Telephlebiidae; Theischinger & Endersby 2009, under Aeshnidae, Brachytronidae and Telephlebiidae; Theischinger 2012).

Adversaeschna brevistyla (Rambur, 1842)

Fig. 15

Ris (1910), as larva D, Tillyard (1910a, 1914, 1916a, 1916b, 1917b, 1926), Watson (1962), O'Farrell (1970), Allbrook (1979), Williams (1980), Hawking (1986), Watson & O'Farrell (1991, 1994), Hawking & Theischinger (1999), Theischinger & Hawking (2003), all as *Aeshna brevistyla*; Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of the genus in Australia.

Agyrtacantha dirupta (Karsch, 1889)

Larva not yet recognized. Sole species of the genus in Australia.

Anaciaeschna jaspidea (Burmeister, 1839)

Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of the genus in Australia.

Anax georgius Selys, 1872

Watson & Theischinger (1987); Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Anax gibbosulus Rambur, 1842

Fig. 16

Watson & Theischinger (1987); Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Anax guttatus (Burmeister, 1839)

Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Anax papuensis (Burmeister, 1839)

Fig. 85

Tillyard (1916a, 1916b, 1917b, 1932); Calvert (1934); Watson (1962, 1968); Allbrook (1979); Hawking (1986, 1993, 1995), Hawking & Smith (1997); Ingram *et al.* (1997); Hawking & Theischinger (1999); Gooderham & Tsyrlin (2002), as *Aeshna brevistyla*; Theischinger (2002); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Up to 2006 most generally referred to as *Hemianax papuensis*.

Genus ***Anax*** Leach, 1815

Morphological characters are insufficient to distinguish among species. Identifications of larvae from southern, inland and central Australia can be confirmed by distribution as *A. papuensis*. In northern Australia the other three species may coexist with each other (*A. georgius* most restricted and morphologically distinct) and *A. papuensis* (Theischinger 2002; Theischinger & Endersby 2009).

Austrogynacantha heterogena Tillyard, 1908

Fig. 17

Hawking (1993); Hawking & Theischinger (1999); Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Gynacantha dobsoni Fraser, 1951

Tillyard (1916a, 1917b), as *G. rosenbergi*; Hawking (1993); Theischinger (2007b); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Gynacantha kirbyi Krüger, 1898

Larva not yet recognized.

Gynacantha mocsaryi Förster, 1898

Fraser (1963), somewhat incorrect; Theischinger (2001c, 2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Gynacantha nourlangie Theischinger & Watson, 1991

Hawking (1993); Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Gynacantha rosenbergi Kaup, 1867

Theischinger (2007b); Theischinger & Endersby (2009). Tillyard (1916a), as *G. rosenbergi* described the larva of *G. dobsoni*.

*Genus ***Gynacantha*** Rambur, 1842

Distributions cannot be used to confirm identifications based on morphology. *G. kirbyi* and *G. mocsaryi* appear to be restricted to north-eastern Queensland, but the other more widely distributed species occur there as well (Theischinger & Endersby 2009).

Dendroaeschna conspersa (Tillyard, 1907)

Fig. 18

Tillyard (1914, 1916a, 1916b, 1917b); Hawking (1991); Hawking & Theischinger (1999); Theischinger (2002); Theischinger & Hawking (2006); Peters & Theischinger (2007); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Acanthaeschna victoria Martin, 1901

Fig. 19

Theischinger (2000a, 2000c, 2002, 2008a); Theischinger & Hawking (2006); Peters & Theischinger (2007); Theischinger & Endersby (2009); Theischinger & Jacobs (2012); Hawking *et al.* (2013). Genus monotypic.

Antipodophlebia asthenes (Tillyard, 1916)

Watson & Theischinger (1980); Hawking & Theischinger (1999); Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Austroaeschna (Austroaeschna) christine Theischinger, 1993

Theischinger (1993, 2002); Theischinger & Hawking (2006); Peters & Theischinger (2007); Theischinger & Endersby (2009).

Austroaeschna (Austroaeschna) ingrid Theischinger, 2008

Theischinger (2008b); Theischinger & Endersby (2009).

Austroaeschna (Austroaeschna) multipunctata (Martin, 1901)

Theischinger (1982, 2002), Hawking (1986), Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Peters & Theischinger (2007); Theischinger & Endersby (2009). The description of *A. multipunctata* by Tillyard (1916a) refers to *A. obscura*.

Austroaeschna (Austroaeschna) obscura Theischinger, 1982

Tillyard (1916a, 1916b, 1917b), as *A. multipunctata*; Hawking & Theischinger (1999); Theischinger (1982, 2002, 2012); Theischinger & Hawking (2006); Peters & Theischinger (2007); Theischinger & Endersby (2009).

Austroaeschna (Austroaeschna) parvistigma (Selys, 1883)

Tillyard (1916a), from notes only; Allbrook (1979); Theischinger (1993, 2002); Hawking (1986); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Peters & Theischinger (2007); Theischinger & Endersby (2009).

Austroaeschna (Austroaeschna) sigma Theischinger, 1982

Theischinger (1982, 1993, 2002); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus ***Austroaeschna***, Subgenus ***Austroaeschna*** Selys, 1883

Only *A. obscura* can be distinguished from congeners on the basis of morphology. Four more species can confidently be identified by their distributions. Eungella area: *A. christine*; south-eastern Queensland and New South Wales N of latitude Sydney: *A. sigma*; south-eastern New South Wales south of approximately 35°30'S and Victoria except for the Grampians: *A. multipunctata*; Grampians: *A. ingrid*. *A. parvistigma* is the only species in Tasmania. On the mainland it may, however, coexist in places with with *A. sigma*, *A. multipunctata* and *A. ingrid*. But, whereas the larvae of these three species inhabit running water often with rocky substrate, the larva of *A. parvistigma* is usually found only in swampy and boggy situations (Theischinger 2002, 2012; Theischinger & Endersby 2009).

Austroaeschna (Glaciaeschna) flavomaculata Tillyard, 1916

Theischinger (1982, 2002, 2012); Hawking (1986); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009). Subgenus monotypic.

Austroaeschna (Montiaeschna) atrata Martin, 1901

Theischinger (1982, 2002, 2012); Hawking (1986, 1995); Hawking & Watson (1990); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Peters & Theischinger (2007); Theischinger & Endersby (2009); Hawking *et al.* (2013). The description of *A. atrata* by Tillyard (1916a) refers to the larva of *A. subapicalis*.

Austroaeschna (Montiaeschna) hardyi Tillyard, 1917

Allbrook (1979); Theischinger (1982, 2002); Theischinger & Hawking (2006); Peters & Theischinger (2007); Theischinger & Endersby (2009).

Austroaeschna (Montiaeschna) subapicalis Theischinger, 1982

Tillyard (1916a), as *A. atrata*; Theischinger (1982, 2002, 2012); Theischinger & Hawking (2003, 2006); Peters & Theischinger (2007); Theischinger & Endersby (2009).

Austroaeschna (Montiaeschna) tasmanica Tillyard, 1916

Allbrook (1979); Theischinger (1982, 2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus ***Austroaeschna***, Subgenus ***Montiaeschna*** Theischinger, 2012

Of the two very similar mainland species, *A. atrata* seems to be restricted to the alpine region, whereas *A. subapicalis* may reach north into Queensland and in the south certainly reaches west to the Grampians. The two Tasmanian species can be identified based on morphology only (Theischinger 2002, 2012).

Austroaeschna (Occidaeschna) anacantha Tillyard, 1908

Ris (1910), as larva C; Tillyard (1916a), as *Acanthaeschna anacantha*; Watson (1962); Theischinger (1982, 2002, 2012); Watson *et al.* (1991); Theischinger & Hawking (2006); Theischinger & Endersby (2009). Subgenus monotypic. Morphology based identification can be confirmed by distribution: only south-western Australia.

Austroaeschna (Petersaeschna) cooloola Theischinger, 1991

Hawking & Theischinger (1999), as *A. unicornis cooloola*; Theischinger (2002, 2012); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austroaeschna (Petersaeschna) inermis Martin, 1901

Theischinger (1975, 1982, 2002, 2012); Hawking (1986); Hawking & Smith (1997); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Austroaeschna (Petersaeschna) pinheyi Theischinger, 2001

Theischinger (1982), Hawking & Theischinger (1999), both partly as *A. unicornis speciosa*; Theischinger (2001b, 2002), Theischinger & Hawking (2006), all as *Austroaeschna unicornis pinheyi*; Peters & Theischinger (2007); Theischinger & Endersby (2009).

Austroaeschna (Petersaeschna) speciosa Sjöstedt, 1917

Theischinger (1982, 2002); Theischinger & Hawking (2006); Peters & Theischinger (2007); Theischinger & Endersby (2009). Hawking & Theischinger (1999), as *A. unicornis speciosa* should be referred to *A. pinheyi* and *A. unicornis*.

Austroaeschna (Petersaeschna) unicornis (Martin, 1901)

Tillyard (1916a), Albrook (1979), both as *A. longissima*; Theischinger (1982, 2002, 2012); Hawking (1986); Hawking & Theischinger (1999); Gooderham & Tsyrlin (2002); Theischinger & Hawking (2003, 2006); Peters & Theischinger (2007); Theischinger & Endersby (2009).

*Genus ***Austroaeschna***, Subgenus ***Petersaeschna*** Theischinger, 2012

Distributions can at least in part support identification of four of the five species. Tropical Queensland north of Paluma-Eungella gap: *A. speciosa*; inland Queensland: *A. pinheyi*; Cooloola region, Stradbroke Island and Fraser Island: *A. cooloola;* most of eastern Queensland south of Paluma-Eungella gap, eastern New South Wales, Victoria, Tasmania, South Australia: *A. unicornis*. There is no need for confirming identification of *A. inermis* on geography (Theischinger 2002, 2012).

Austroaeschna (Pulchaeschna) eungella Theischinger, 1993

Theischinger (1993, 2002); Theischinger & Hawking (2006); Peters & Theischinger (2007); Theischinger & Endersby (2009).

Austroaeschna (Pulchaeschna) muelleri Theischinger, 1982

Fig. 20

Theischinger (1982, 1993, 2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austroaeschna (Pulchaeschna) pulchra Tillyard, 1909

Tillyard (1916a) as *A. unicornis*; Fraser (1959) as *A. unicornis pulchra*; Theischinger (1982, 1993, 2002, 2012); Hawking (1986); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

*Genus ***Austroaeschna***, Subgenus ***Pulchaeschna*** Peters & Theischinger, 2007

Identification of all species can be confirmed by distributions. Eungella region and Clarke Range: *A. eungella*; Carnarvon Range in southern inland Queensland: *A. muelleri*; most of eastern Australia south of Eungella area: *A. pulchra* (Theischinger 2002, 2012).

*Genus ***Austroaeschna*** Selys, 1883

The five subgenera *Austroaeschna*, *Glaciaeschna*, *Montiaeschna*, *Occidaeschna*, *Petersaeschna* and *Pulchaeschna* are clearly separable on morphological differences (Theischinger 2012).

Austrophlebia costalis (Tillyard, 1907)

Fig. 21

Tillyard (1916a); Theischinger (1982, 1996, 2002, 2012); Hawking & Theischinger 1999); Theischinger & Hawking (2006); Peters & Theischinger (2007); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Austrophlebia subcostalis Theischinger, 1996

Theischinger (1996, 2002); Theischinger & Hawking (2006); Peters & Theischinger (2007); Theischinger & Endersby (2009).

*Genus ***Austrophlebia*** Tillyard, 1916

Identification can be confirmed by specific distributions. North of Eungella-Paluma gap: *A. subcostalis*; south of Eungella-Paluma gap: *A. costalis* (Theischinger 2002). However, the adults of both these species fly very well, and overlap in distribution of the two species cannot completely be excluded.

Dromaeschna forcipata (Tillyard, 1907)

Theischinger (1982, 2002), Theischinger & Hawking (2006), all as *Austroaeschna forcipata*; Theischinger & Endersby (2009); Theischinger (2012).

Dromaeschna weiskei (Förster, 1908)

Theischinger (1982, 2002); Theischinger & Hawking (2006), all as *Austroaeschna weiskei*; Theischinger & Endersby (2009); Theischinger (2012).

*Genus ***Dromaeschna*** Förster, 1908

Reliable identification of the two often coexisting species can be achieved based on morphology (Theischinger 1982; Theischinger & Endersby 2009).

Notoaeschna geminata Theischinger, 1982

Tillyard (1916a), as *N. sagittata*; Theischinger (1982, 2002); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Notoaeschna sagittata (Martin, 1901)

Fig. 86

O'Farrell (1970); Theischinger (1982, 2002); Hawking (1986); Watson & O'Farrell (1991); Watson *et al.* (1991); Hawking & Smith (1997); Hawking & Theischinger (1999); Gooderham & Tsyrlin (2002); Theischinger & Hawking (2003, 2006); Peters & Theischinger (2007); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Notoaeschna*** Tillyard, 1916

At present confident identification of the two species is possible only by their specific distributions. North of the Hunter River: *N. geminata*; south of the Hunter River: *N. sagittata* (Theischinger 2002).

Spinaeschna tripunctata (Martin, 1901)

Fig. 22

Theischinger (1975, 1982, 2002); Hawking (1986, 1995); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Peters & Theischinger (2007); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Spinaeschna watsoni Theischinger, 1982

Theischinger (1982, 2002); Theischinger & Hawking (2006); Peters & Theischinger (2007); Theischinger & Endersby (2009).

*Genus ***Spinaeschna*** Theischinger, 1982

Identification can be confirmed by specific distributions. North of Eungella-Paluma gap: *S. watsoni*; New South Wales and Victoria: *S. tripunctata* (Theischinger 2002).

Telephlebia brevicauda Tillyard, 1916

Fig. 23

O'Farrell (1970); Watson & O'Farrell (1991); Hawking (1986); Hawking & Theischinger (1999); Theischinger (2002); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Telephlebia cyclops Tillyard, 1916

Hawking & Theischinger (1999); Theischinger (2002); Theischinger & Hawking (2003, 2006); Peters & Theischinger (2007); Theischinger & Endersby (2009).

Telephlebia godeffroyi Selys, 1883

Tillyard (1916a); Watson & Theischinger (1980); Hawking & Theischinger (1999); Theischinger (2002); Theischinger & Hawking (2003, 2006); Peters & Theischinger (2007); Theischinger & Endersby (2009).

Telephlebia tillyardi Campion, 1916

Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Telephlebia tryoni Tillyard, 1917

Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Telephlebia undia Theischinger, 1985

Larva not yet recognized.

*Genus ***Telephlebia*** Selys, 1883

Two 'species groups' can be distinguished based on the shape of the paraprocts of male final instar larvae. Geography helps specific identification (Theischinger 2002). Group A: North of Paluma-Eungella gap: *A. tillyardi*; Carnarvon N. P.: *T. undia* (but larva still undescribed); coastal south-eastern Queensland: *T. tryoni*. Group B: Coastal south-eastern Queensland: *T. cyclops*; south-eastern NSW south to approximately 35°S: *T. godeffroyi*; NSW south of 35°S and Victoria: *T. brevicauda*. *Telephlebia* larvae from north-eastern New South Wales may belong to either *T. cyclops* or T. *godeffroyi*.

Family **Petaluridae**

A single genus clearly distinguishable on morphology (Theischinger & Hawking 2006; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Petalura gigantea Leach, 1815

Tillyard (1909a, 1910a, 1911a, 1917b, 1926), Schmidt (1941); Watson (1958), incorrect; Williams (1980); Hawking & Theischinger (1999); Gooderham & Tsyrlin (2002); Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Petalura hesperia Watson, 1958

Fig. 24

Watson (1958, 1962); Williams (1980); Watson & O'Farrell (1991); Watson *et al.* (1991); Theischinger (2002); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Petalura ingentissima Tillyard, 1908

Andress (1998); Theischinger (2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Petalura litorea Theischinger, 1999

Theischinger (2000a, 2002); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Petalura pulcherrima Tillyard, 1913

Status doubtful (Ware *et al.* 2014).

*Genus ***Petalura*** Leach, 1815

Distributions support identifications based on morphology (Theischinger 2002). Cape York and north-eastern Queensland north of Paluma- Eungella gap: *P. ingentissima/?pulcherrima*; coastal south-eastern Queensland and coastal north-eastern New South Wales: *P. litorea*; montane south-eastern Queensland and most of eastern New South Wales: *P. gigantea*; south-western Australia: *P. hesperia*.

Family Gomphidae

Two subfamilies, seven genera and several subgenera clearly distinguishable on morphology (Theischinger & Hawking 2006, Theischinger & Endersby 2009, both under Gomphidae and Lindeniidae; Hawking *et al.* 2013).

Ictinogomphus australis (Selys, 1873)

Figs 25, 87

Tillyard (1917b); Hawking (1993); Hawking & Smith (1997); Theischinger (1998d, 2000b); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Ictinogomphus dobsoni (Watson, 1969)

Theischinger (1998d, 2000b); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Ictinogomphus paulini Watson, 1991

Larva not yet recognized.

*Genus ***Ictinogomphus*** Cowley, 1934

Distributions largely support identifications based on morphology (Theischinger 2000b; Theischinger & Endersby (2009). Most of eastern and northern Australia: *I. australis*; Pilbara area and further west in Western Australia: *I. dobsoni. Ictinogomphus* larvae from the tip of Cape York may belong to either *I. australis* or *I. paulini.*

Antipodogomphus acolythus (Martin, 1901)

Figs 26, 88

Tillyard (1917b), as *Austrogomphus manifestus*; Fraser (1959), most probably as *A. proselythus*; Theischinger (1998d, 2000b); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Antipodogomphus dentosus Watson, 1991

Hawking (1993); Theischinger (1998d, 2000b); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Antipodogomphus edentulus Watson, 1991

Larva not yet recognized.

Antipodogomphus hodgkini Watson, 1969

Theischinger (1998d, 2000b); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Antipodogomphus neophytus Fraser, 1958

Hawking (1993); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Antipodogomphus proselythus (Martin, 1901)

Theischinger (2007a); Theischinger & Endersby (2009). Fraser (1959) most probably has to be referred to *A. acolythus*.

*Genus ***Antipodogomphus*** Fraser, 1951

Confident identifications based on morphology are not possible at present. Only *A. hodgkini* has an exclusive range (Western Australia: Pilbara area), and *A. acolythus* seems to be the only species of the genus in New South Wales and Victoria (Theischinger 2000b; Theischinger & Endersby 2009).

Armagomphus armiger (Tillyard, 1913)

Fig. 27

Watson (1962, 1991), as *Hemigomphus armiger*; Theischinger (1998d, 2000b); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Austroepigomphus* (*Austroepigomphus*) *praeruptus (Selys, 1857)

Fig. 28

Theischinger (1998d, 2000b), Hawking & Theischinger (1999), Theischinger (2004), all as *Austrogomphus melaleucae*; Theischinger & Hawking (2006); Theischinger & Endersby (2009). Subgenus monotypic.

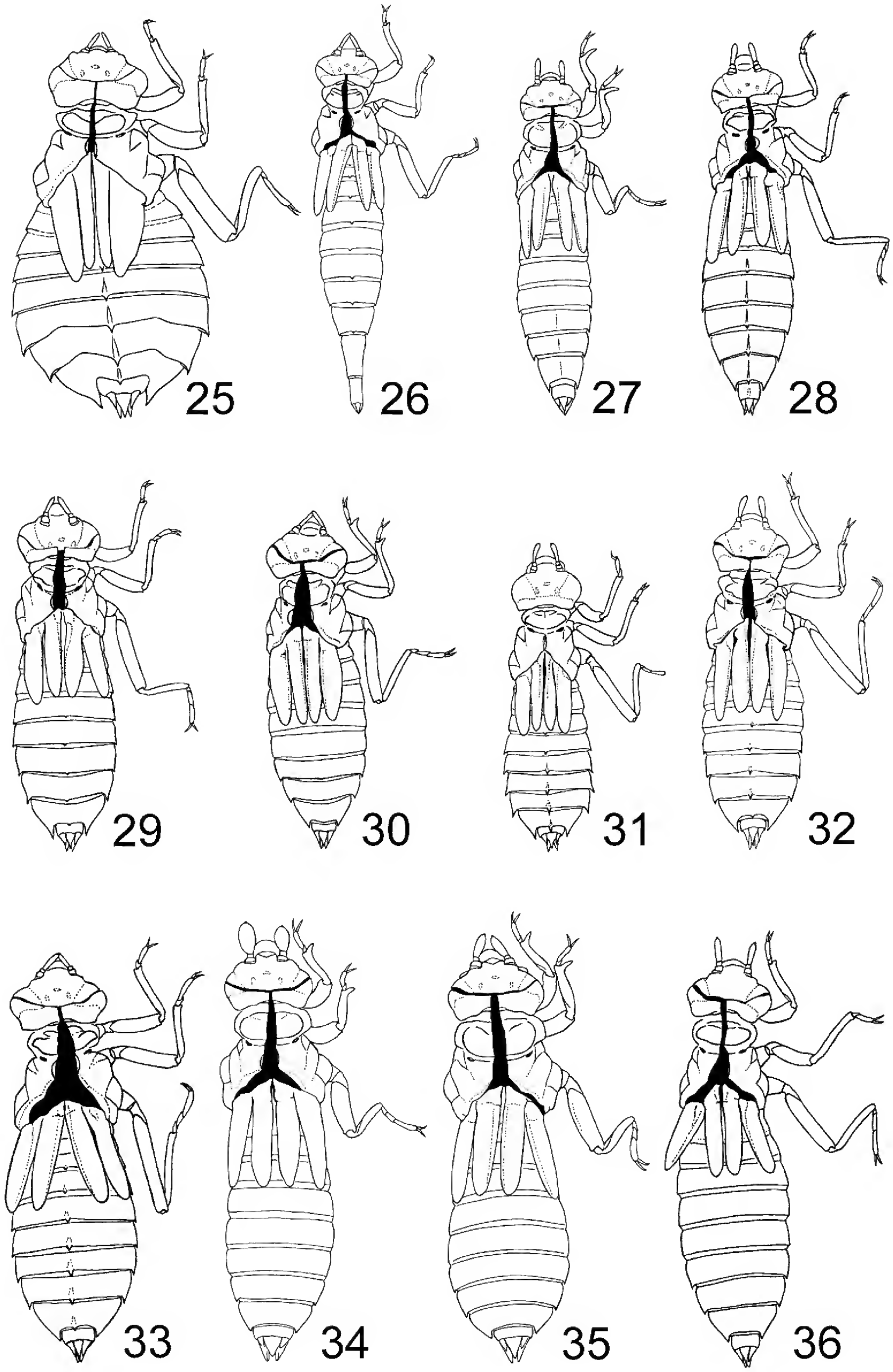
Austroepigomphus* (*Xerogomphus*) *gordoni (Watson, 1962)

Watson (1962), as *Austrogomphus gordoni*; Theischinger (1998d, 2000b);Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austroepigomphus* (*Xerogomphus*) *turneri (Martin, 1901)

Fig. 89

Hawking (1993); Theischinger (1998d, 2000b; 2004); Theischinger & Hawking (2006); Theischinger & Endersby (2009).



Figs 25-36. Final instar larvae of Australian Gomphidae: (25) *Ictinogomphus australis*; (26) *Antipodogomphus acolythus*; (27) *Armagomphus armiger*; (28) *Austroepigomphus paeruptus*; (29) *Austrogomphus (A.) australis*; (30) *A. (A.) cornutus*; (31) *A. (A.) mjobergi*; (32) *A. (A.) ochraceus*; (33) *Austrogomphus (Pleiogomphus) amphiclitus*; (34) *Hemigomphus heteroclytus*; (35) *Odontogomphus donnellyi*; (36) *Zephyrogomphus lateralis*.

*Genus ***Austroepigomphus***, Subgenus ***Xerogomphus*** Watson, 1991

Distributions confirm identifications (on the basis of morphology) of the two species (Theischinger 2000b, 2004). Central and Western Australia: *A. gordoni*; north-eastern and northern Australia: *A. turneri*.

*Genus ***Austroepigomphus*** Fraser, 1951

South-eastern, rarely north-eastern, Australia: subgenus *Austroepigomphus*; north-eastern, central and western Australia: subgenus *Xerogomphus* (Theischinger 2000b, 2004).

Austrogomphus* (*Austrogomphus*) *angelorum Tillyard, 1913

Larva not yet recognized.

Austrogomphus* (*Austrogomphus*) *arbustorum Tillyard, 1906

Theischinger (1998d, 2000b); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austrogomphus* (*Austrogomphus*) *australis Dale, 1854

Fig. 29

Hawking (1986, 1995); Theischinger (1998d, 2000b); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austrogomphus* (*Austrogomphus*) *collaris Hagen, 1854

Watson (1962); Watson *et al.* (1991); Theischinger (1998d, 2000b); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austrogomphus* (*Austrogomphus*) *cornutus Watson, 1991

Fig. 30

Hawking (1986), as *Austrogomphus* sp. "c"; Hawking & New (1996); Theischinger (1998d, 2000b); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Austrogomphus* (*Austrogomphus*) *doddi Tillyard, 1909

Larva not yet recognized.

Austrogomphus* (*Austrogomphus*) *guerini (Rambur, 1842)

O'Farrell (1970); Allbrook (1970); Hawking (1986); Watson & O'Farrell (1991); Watson et al. (1991), Hawking & Smith (1997), as *A. ochraceus*; Theischinger (1998d, 2000b); Hawking & Theischinger (1999); Gooderham & Tsyrlin (2002); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Austrogomphus* (*Austrogomphus*) *mjobergi Sjöstedt, 1917

Fig. 31

Hawking (1993); Theischinger (1998d, 2000b); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austrogomphus* (*Austrogomphus*) *mouldsorum Theischinger, 1999

Larva not yet recognized.

Austrogomphus* (*Austrogomphus*) *ochraceus (Selys, 1869)

Fig. 32

Tillyard (1916b, 1917b, 1926); Hawking (1986); Hawking & New (1996); Theischinger (1998d, 2000b, 2004); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Austrogomphus* (*Austrogomphus*) *pusillus Sjöstedt, 1917

Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus ***Austrogomphus***, Subgenus ***Austrogomphus*** Selys, 1854

The larvae of two species, *A. angelorum*, probably restricted, if still surviving, to the mature Murray River, and *A. mouldsorum*, a large species possibly endemic to the Kimberley, are still undescribed and assumed to be recognisable when found. Other than that a single species and four twin groups can confidently be separated based on morphology. Three of the twin groups are identifiable to the species by allopatry. Only *A. guerini* and *A. ochraceus* cannot be distinguished at present. Of these two only *A. guerini* is found in South Australia and Tasmania (Theischinger 2000b; Theischinger & Endersby 2009).

Austrogomphus* (*Pleiogomphus*) *amphiclitus (Selys, 1873)

Fig. 33

Theischinger (1998d, 2000b, 2004); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austrogomphus* (*Pleiogomphus*) *bifurcatus Tillyard, 1909

Theischinger (1998d, 2000b); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Austrogomphus* (*Pleiogomphus*) *divaricatus Watson, 1991

Larva not available or inseparable from *A. bifurcatus*.

Austrogomphus* (*Pleiogomphus*) *prasinus Tillyard, 1906

Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus **Austrogomphus**, Subgenus **Pleiogomphus** Watson, 1991

Of the four species only *A. amphiclitus* can confidently be identied on morphology, and it is also the only species found over much of eastern and inland Queensland and New South Wales, whereas the other three species are apparently restricted to north-eastern Queensland (Theischinger 2000b; Theischinger & Endersby 2009).

*Genus **Austrogomphus** Selys, 1854

The larvae of the two subgenera *Austrogomphus* and *Pleiogomphus* are clearly separable on morphological differences (Theischinger 2000b; Theischinger & Endersby 2009).

Hemigomphus atratus Watson, 1991

Larva not yet recognized.

Hemigomphus comitatus (Tillyard, 1909)

Theischinger (1998d, 2000b); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Hemigomphus cooloola Watson, 1991

Theischinger (1998d, 2000b); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Hemigomphus gouldii (Selys, 1854)

Williams (1980); Hawking (1986); Hawking & New (1996); Hawking & Smith (1997); Theischinger (1998d, 2000b); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Hemigomphus heteroclytus Selys, 1854

Figs 34, 90

Tillyard (1910a, 1914, 1916b, 1917b); Hawking (1986); Theischinger (1998d, 2000b); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Hemigomphus magela Watson, 1991

Hawking (1993); Theischinger (1998d, 2000b); Theischinger & Hawking (2006); Peters & Theischinger (2007); Theischinger & Endersby (2009).

Hemigomphus theischingeri Watson, 1991

Theischinger (1998d, 2000b); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

*Genus **Hemigomphus** Selys 1854

H. cooloola and *H. magela* have characters different from the morphologically rather uniform remaining species. In addition *H. magela* has a restricted geographical range within the Northern Territory, whereas *H. atratus* (larva still unknown), *H. comitatus* and *H. theischingeri* are restricted to north-eastern Queensland and *H. gouldii* and *H. heteroclytus* are more or less confined to south-eastern Australia. Only *H. heteroclytus*, the only *Hemigomphus* occurring in southern inland Queensland, slightly overlaps the range of the three north-eastern species (Theischinger 2000b; Theischinger & Endersby 2009).

Odontogomphus donnellyi Watson, 1991

Fig. 35

Watson (1991), under Genus *Odontogomphus*; Theischinger (1998d, 2000b); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Zephyrogomphus lateralis (Selys, 1873)

Fig. 36

Watson (1962), as *Austrogomphus lateralis*; Theischinger (1998d, 2000b); as *Austrogomphus (Zephyrogomphus) lateralis*; Theischinger (2004); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Zephyrogomphus longipositor (Watson, 1991)

Theischinger (1998d, 2000b), as *?Austrogomphus (?Zephyrogomphus) longipositor*; Theischinger (2004); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus **Zephyrogomphus** Watson, 1991

Widely disjunct distributions confirm identification based on morphology of the two species (Theischinger 2000b; Theischinger & Endersby 2009).

Family **Synthemistidae**

Eight genera distinguishable on morphology, two of them, *Choristhemis* and *Eusynthemis* difficult (Theischinger & Hawking 2006; Theischinger & Endersby 2009; Hawking *et al.* 2013).

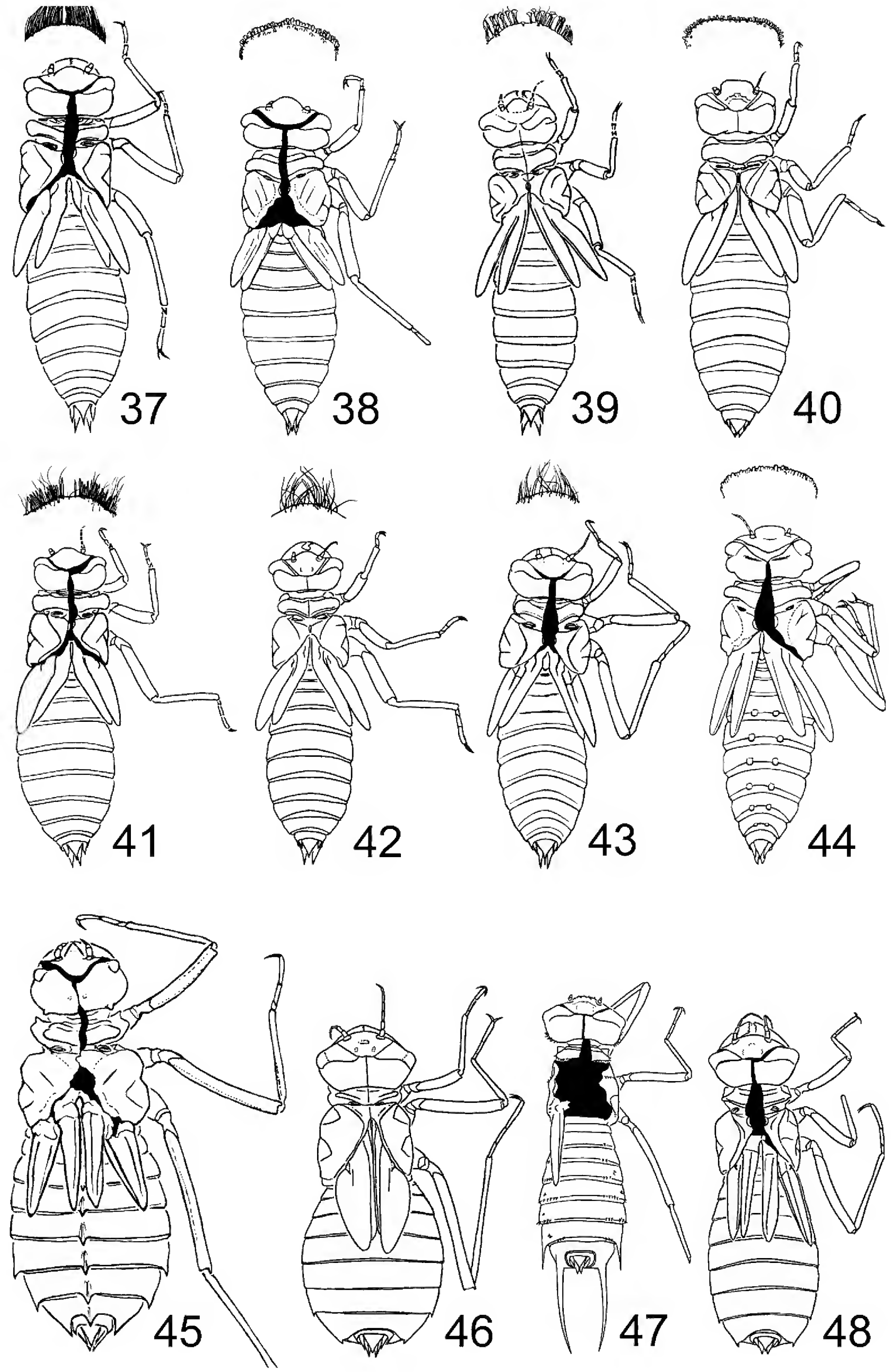
Archaeosynthemis leachii (Selys, 1871)

Fig. 37

Watson (1967); Watson *et al.* (1991); Theischinger (2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Archaeosynthemis occidentalis (Tillyard, 1910)

Watson (1962, 1967), Watson & O'Farrell (1991, 1994), all as *Synthemis macrostigma*; Watson *et al.* (1991), as *Synthemis macrostigma occidentalis*; Theischinger (2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009).



Figs 37-48. Final instar larvae of Australian Anisoptera: (37-44) Synthemistidae (with insert of frontal plate): (37) *Archaeosynthemis leachii*; (38) *Austrosynthemis cyanitincta*; (39) *Choristhemis flavoterminata*; (40) *Eusynthemis ursula*; (41) *Parasynthemis regina*; (42) *Synthemiopsis gomphomacromioides*; (43) *Synthemis eustalacta*; (44) *Tonyosynthemis claviculata*; (45) *Macromia tillyardi* (Macromiidae); (46-48) Corduliidae: (46) *Hemicordulia tau*; (47) *Pentathemis mebranulata*; (48) *Procordulia jacksoniensis*.

Archaeosynthemis orientalis (Tillyard, 1910)

Tillyard (1910b, 1914, 1916b, 1917b), O'Farrell (1970), Allbrook (1979), Hawking (1986), Watson & O'Farrell (1991), Watson *et al.* (1991), all as *Synthemis macrostigma*; Hawking & Theischinger (1999), as *Archaeosynthemis macrostigma*; Theischinger (2001a); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Archaeosynthemis spiniger (Tillyard, 1913)

Watson (1962, 1967), as *Synthemis spiniger*; Theischinger (2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus ***Archaeosynthemis*** Carle, 1995

Confident identifications based on morphology can be achieved for the three south-western Australian species *S. leachii*, *S. occidentalis* and *S. spiniger*; *S. orientalis* is the only species from south-eastern Australia (Theischinger 2001a; Theischinger & Endersby 2009).

Austrosynthemis cyanitincta (Tillyard, 1908)

Fig. 38

Watson (1962, 1967), as *Synthemis cyanitincta*; Watson *et al.* (1991); Theischinger (1998a, 2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Choristhemis flavoterminata (Martin, 1901)

Fig. 39

Tillyard (1910b); Hawking & Theischinger (1999); Theischinger (2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Choristhemis olivei (Tillyard, 1909)

Theischinger (2003); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus ***Choristhemis*** Tillyard, 1910

Confident morphology based identifications should be possible (Theischinger 2001a, 2003), but all larvae from south of the Daintree River, certainly from south of the Paluma-Eungella gap, can be confirmed as *C. flavoterminata*.

Eusynthemis aurolineata (Tillyard, 1913)

Theischinger (1998e); Hawking & Theischinger (1999); Theischinger (2001); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Eusynthemis barbarae (Moulds, 1985)

Theischinger (2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Eusynthemis brevistyla (Selys, 1871)

Hawking (1986, 1995); Hawking & Theischinger (1999); Theischinger (2001a); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Eusynthemis deniseae Theischinger, 1977

Theischinger (1977, 2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Eusynthemis guttata (Selys, 1871)

Theischinger (1995, 1998e, 2001a); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009). Tillyard (1910b) and Hawking (1986) have to be referred to *E. tillyardi*.

Eusynthemis netta Theischinger, 1999

Larva not yet recognized.

Eusynthemis nigra (Tillyard, 1906)

Hawking & Theischinger (1999); Theischinger (2001a); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Eusynthemis rentziana Theischinger, 1998

Theischinger (1998e; 2001a); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

Eusynthemis tenera Theischinger, 1995

Larva not yet recognized.

Eusynthemis tillyardi Theischinger, 1995

Tillyard (1910b, 1916b), Hawking (1986), all as *E. guttata*; Theischinger (1995, 1998e); Hawking & Theischinger (1999); Theischinger (2001a); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Eusynthemis ursa Theischinger, 1999

Larva not yet recognized.

Eusynthemis ursula Theischinger, 1998

Fig. 40

Theischinger (2000a, 2001a); Theischinger & Hawking (2000, 2006); Theischinger & Endersby (2009).

Eusynthemis virgula (Selys, 1874)

Fig. 91

Hawking (1986); Hawking & Theischinger (1999); Theischinger (2001a); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009).

*Genus ***Eusynthemis*** Förster, 1903

Based on the morphology of the described larvae three groups can be distinguished: *E. ursula*; *E. brevistyla* and *E. virgula*; the remaining species (Theischinger 2001a; Theischinger & Endersby 2009). It is supposed that *E. ursa* (larva still undescribed) will closely resemble *E. ursula* and that *E. netta,* the adults of which are quite distinct, will be recognisable when found. Firm geographical support for specific identification is not available but the specific ranges (Theischinger 2001a; Theischinger & Endersby 2009) should be looked at when morphology based results appear doubtful.

Parasynthemis regina (Selys, 1874)

Fig. 41

Tillyard (1910b), Hawking (1986), both as *Synthemis regina*; Hawking & Theischinger (1999); Theischinger (2001a); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Synthemiopsis gomphomacromioides Tillyard, 1917

Fig. 42

Theischinger (2000d, 2001a); Gooderham & Tsyrlin (2002), as *Synthemiopsis*; Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Tillyard (1917b), Allbrook (1979), both to be referred to a different synthemistid species. Genus monotypic.

Synthemis eustalacta (Burmeister, 1839)

Fig. 43

Tillyard (1910b, 1917b, 1926); O'Farrell (1970); Williams (1980); Hawking (1986); Watson & O'Farrell (1991, 1994); Hawking & Smith (1997); Hawking & Theischinger (1999); Theischinger (2001a, 2010); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Synthemis tasmanica Tillyard, 1910

Allbrook (1979); Theischinger (2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus ***Synthemis*** Selys, 1870

Confirmation of morphology based specific identification by available distributions (Theischinger 2001a; Theischinger & Endersby 2009)). Mainland Australia: *S. eustalacta*; Tasmania: *S. tasmanica*. However, *Synthemis* larvae from the west of Victoria and eastern South Australia agree with *S. tasmanica* and may well be this species.

Tonyosynthemis claviculata (Tillyard, 1909)

Fig. 44

Theischinger 1998a, 2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Tonyosynthemis ofarrelli (Theischinger & Watson, 1986)

Theischinger (1998a, 2001a, 2010); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Tonyosynthemis*** Theischinger, 1998

Confident specific identification possible only by considering distributions (Theischinger 1998a, 2001a). North of Paluma-Eungella gap: *T. claviculata*; south-eastern Queensland and north-eastern New South Wales: *T. ofarrelli*.

Family **Macromiidae**

Only a single genus clearly distinguishable on morphology (Theischinger & Hawking 2006; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Macromia tillyardi Martin, 1906

Fig. 45

Hawking (1993); Theischinger (2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Macromia viridescens Tillyard, 1911

Theischinger (2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus ***Macromia*** Rambur, 1842

Identifications are reliable based on morphology (Theischinger 2001). It seems clear that *M. viridescens* is restricted to Cape York peninsula but existence there of *M. tillyardi* cannot be excluded.

Family **Corduliidae**

Four genera clearly distinguishable on morphology (Theischinger & Hawking 2006, under Corduliidae and Hemicorduliidae; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Hemicordulia australiae (Rambur, 1842)

Watson (1962), O'Farrell (1970); Allbrook (1979); Williams (1980), Hawking (1986); Watson & O'Farrell (1991); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009).

Hemicordulia continentalis Martin, 1907

Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009).

Hemicordulia flava Theischinger & Watson, 1991

Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Hemicordulia intermedia (Selys, 1871)

Hawking (1993); Hawking & Theischinger (1999); Theischinger & Fleck (2003); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009).

Hemicordulia kalliste Theischinger & Watson, 1991

Larva not yet recognized.

Hemicordulia koomina Watson, 1969

Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Hemicordulia superba Tillyard, 1911

Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Hemicordulia tau (Selys, 1871)

Fig. 46

Tillyard (1914, 1915b, 1916b, 1917b, 1926, 1932); Watson (1962, 1968); O'Farrell (1970); Allbrook (1979); Williams (1980); Hawking (1986, 1993, 1995); Watson & O'Farrell (1991); Watson *et al.* (1991); Hawking & Smith (1997); Ingram *et al.* (1997); Hawking & Theischinger (1999); Gooderham & Tsyrlin (2002); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Hemicordulia*** Selys, 1870

The larvae of each of *H. australiae*, *H. flava* and *H. superba* can be identified based on morphology (Theischinger 2007a). Of the morpho-group *H. intermedia* and *H. koomina* only *H. intermedia* has a wide geographical range including northern, central and much of eastern Australia so that only identifications from the Pilbara area are doubtful. Of the morpho-group *H. tau*, *H. continentalis* and *H. kalliste* it appears that *H. kalliste* is the only species at, and restricted to, the extreme north of Australia, whereas *H. tau* is the only one occurring in Western Australia, central and most of southern Australia.

Metaphya tillyardi Ris, 1913

Larva not yet recognized. Sole species of the genus in Australia. Some information on the larva of *M. elongata* Campion, 1921, made available by Fleck (2007) is produced by Theischinger & Endersby (2009) in order to give an idea of what the still undescribed larva of *M. tillyardi* may look like.

Pentathemis membranulata Karsch, 1890

Fig. 47

Hawking (1993); Young (2001); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Procordulia affinis (Selys, 1871)

Watson (1962); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Procordulia jacksoniensis (Rambur, 1842)

Fig. 48

O'Farrell (1970); Allbrook (1979); Hawking (1986); Watson & O'Farrell (1991); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Procordulia*** Martin, 1907

Identifications of the two species based on morphology are confirmed beyond any doubt by their widely disjunct distributions (Theischinger 2007a). Southwestern Australia: *P. affinis*; eastern Australia and South Australia: *P. jacksoniensis*.

Family **Libellulidae**

Of 27 genera four, *Crocothemis*, *Diplacodes*, *Nannodiplax* and *Neurothemis*, are difficult to distinguish from each other, and of two, *Notolibellula* and *Raphismia*, the larvae are still undescribed (Theischinger & Hawking 2006, under Urothemistidae and Libellulidae; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Aethriamanta circumsignata Selys, 1897

Hawking (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013), as *Aethriamanta*.

Aethriamanta nymphaeae Lieftinck, 1949

Fig. 49

Hawking (1993); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

*Genus ***Aethriamanta*** Kirby, 1889

The known morphological characters (Hawking 1993) appear insufficient to distinguish the two species. Only *A. circumsignata* has hitherto been found to occur in New South Wales (Theischinger 2007a; Theischinger & Endersby 2009).

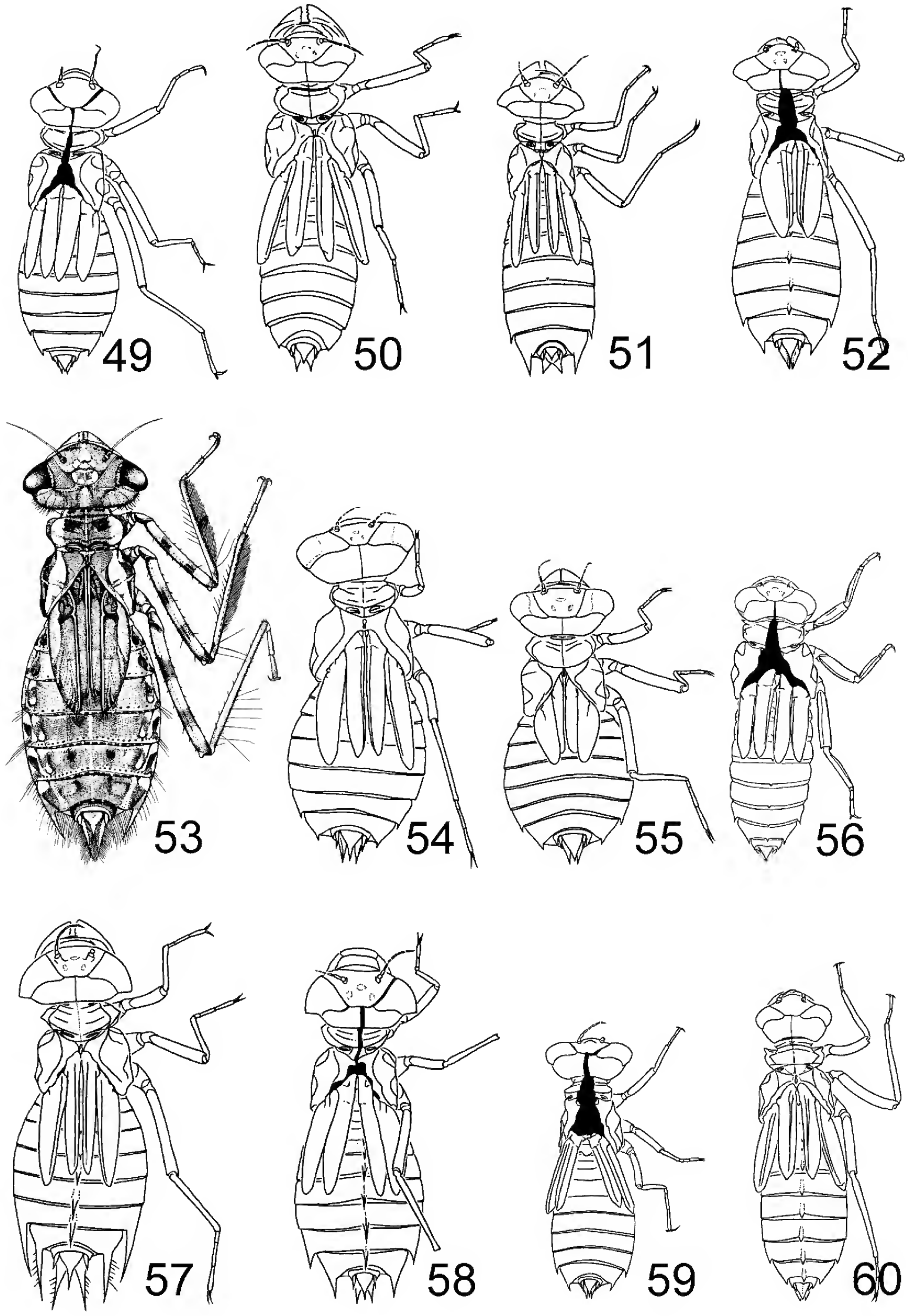
Agrionoptera insignis allogenes Tillyard, 1908

Hawking (1993); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Agrionoptera longitudinalis biserialis Selys, 1879

Fig. 50

Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).



Figs 49-60. Final instar larvae of Australian Libellulidae: (49) *Aethriamanta nymphaeae*; (50) *Agrionoptera longitudinalis*; (51) *Austrothemis nigrescens*; (52) *Brachydiplax denticauda*; (53) *Camacinia gigantea*; (54) *Crocothemis nigrifrons*; (55) *Diplacodes haematodes*; (56) *Huonia melvillensis*; (57) *Hydrobasisleus brevistylus*; (58) *Macrodiplax cora*; (59) *Nannodiplax rubra*; (60) *Nannophlebia risi.*

*Genus **Agrionoptera** Brauer, 1854

The two species can confidently be identified based only on morphology. Only A. *insignis* ranges south and west beyond tropical Queensland (Theischinger 2007a; Theischinger & Endersby 2009).

Austrothemis nigrescens (Martin, 1901)

Fig. 51

Watson (1962); Allbrook (1979); Hawking (1986); Hawking & Smith (1997); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.

Brachydiplax denticauda (Brauer, 1867)

Fig. 52

Hawking (1993); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Brachydiplax duivenbodei (Brauer, 1866)

Larva not yet recognized.

*Genus **Brachydiplax** Brauer, 1868

Only *Brachydiplax* larvae from south of the Paluma-Eungella gap can with high probability be confirmed as *B. denticauda* (Theischinger 2007a).

Camacinia othello Tillyard, 1908

(Fig. 53, *C. gigantea*)

Larva not yet recognized. Sole species of *Camacinia* in Australia. It is assumed that the larva of *C. othello* will be found to be very similar to its closely related congener *C. gigantea* which should be used as a substitute to allow identification of *C. othello* in future (Theischinger & Hawking 2006; Theischinger & Endersby 2009; Hawking *et al.* 2013).

Crocothemis nigrifrons (Kirby, 1894)

Fig. 54

Watson (1962); Hawking (1986, 1993); Hawking & Smith (1997); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of *Crocothemis* in Australia. Difficult to distinguish from *Diplacodes*, *Nannodiplax* and *Neurothemis*.

Diplacodes bipunctata (Brauer, 1865)

Tillyard (1917b, 1926); Lieftinck (1962); Watson (1962); O'Farrell (1970); Hawking (1986, 1993); Watson & O'Farrell (1991); Watson *et al.* (1991); Rowe (1992); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009).

Diplacodes haematodes (Burmeister, 1839)

Fig. 55

Tillyard (1914, 1916b, 1917b); Watson (1962); Williams (1980); Hawking (1986, 1993); Hawking & New (1996); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009).

Diplacodes melanopsis (Martin, 1901)

Hawking (1986); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Diplacodes nebulosa (Fabricius, 1793)

Hawking (1993); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Diplacodes trivialis (Rambur, 1842)

Lieftinck (1962); Kumar (1977); Hawking (1993); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

*Genus **Diplacodes** Kirby, 1889

Morphological differences separate either of *D. haematodes* and *D. melanopsis* from the remainder of this genus and from *Nannodiplax rubra*, whereas *D. bipunctata* morphologically pairs up with *D. trivialis* and *D. nebulosa* pairs up with *N. rubra*. Confident identifications can be achieved for only *D. bipunctata* from Western Australia, central and southern Australia and *N. rubra* from the Kimberley (Theischinger 2007a; Theischinger & Endersby 2009).

Huonia melvillensis Brown & Theischinger, 1998

Fig. 56

Theischinger & Brown (2002); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of *Huonia* in Australia.

Hydrobasileus brevistylus (Brauer, 1865)

Fig. 57

Fraser (1963); Hawking (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of *Hydrobasileus* in Australia.

Lathrecista asiatica festa (Selys, 1879)

Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009). The larva referred to in these three papers was identified by supposition only. Sole species of *Lathrecista* in Australia.

Macrodiplax cora (Kaup, 1867)

Fig. 58

Lieftinck (1962); Watson (1962); Hawking (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of *Macrodiplax* in Australia.

Nannodiplax rubra Brauer, 1868

Fig. 59

Hawking (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009). Genus monotypic. Larva at present indistinguishable from *Diplacodes nebulosa,* but can be identified if found in the Kimberley (see under Genus *Diplacodes*).

Nannophlebia eludens Tillyard, 1908

Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Nannophlebia injibandi Watson, 1969

Hawking (1993); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Nannophlebia mudginberri Watson & Theischinger, 1991

Hawking (1993); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Nannophlebia risi Tillyard, 1913

Fig. 60

Tillyard (1913); Hawking (1986, 1995); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Nannophlebia*** Selys, 1878

Distributions confirm *Nannophlebia* larvae from New South Wales and Victoria as *N. risi.* Larvae from north-eastern Australia may be either *N. risi* or *N. eludens*, whereas larvae from northern and Western Australia may be either *N. eludens*, *N. injibandi* or *N. mudginberri* (Theischinger 2007a; Theischinger & Endersby 2009).

Nannophya australis Brauer, 1865

Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007); Theischinger & Endersby (2009).

Nannophya dalei (Tillyard, 1908)

Fig. 92

Allbrook (1979); Hawking (1986); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Nannophya occidentalis (Tillyard, 1908)

Watson (1962); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009).

Nannophya paulsoni Theischinger, 2003

Larva not yet recognized.

Nannophya sp.

Fig. 61

Status uncertain; known only from larvae from near Barcaldine, Queensland.

*Genus ***Nannophya*** Rambur, 1842

Distributions confirm most of the identifications based on morphology (Theischinger 2007a). Larvae from the very north of Australia may belong to either *N. australis* or *N. paulsoni* (larva still undescribed).

Neurothemis oligoneura Brauer, 1867

Larva not yet recognized.

Neurothemis stigmatizans (Fabricius, 1775)

Fig. 62

Lieftinck (1962); Hawking (1993); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013). Difficult to distinguish from *Crocothemis*, *Diplacodes* and *Nannodiplax.*

*Genus ***Neurothemis*** Brauer, 1867

Neurothemis larvae from the very north of Australia may belong to either *N. stigmatizans* or to *N. oligoneura*, but only *N. stigmatizans* occurs in the Kimberley and in south-eastern Queensland and north-eastern New South Wales (Theischinger 2007a).

Notolibellula bicolor Theischinger & Watson, 1977

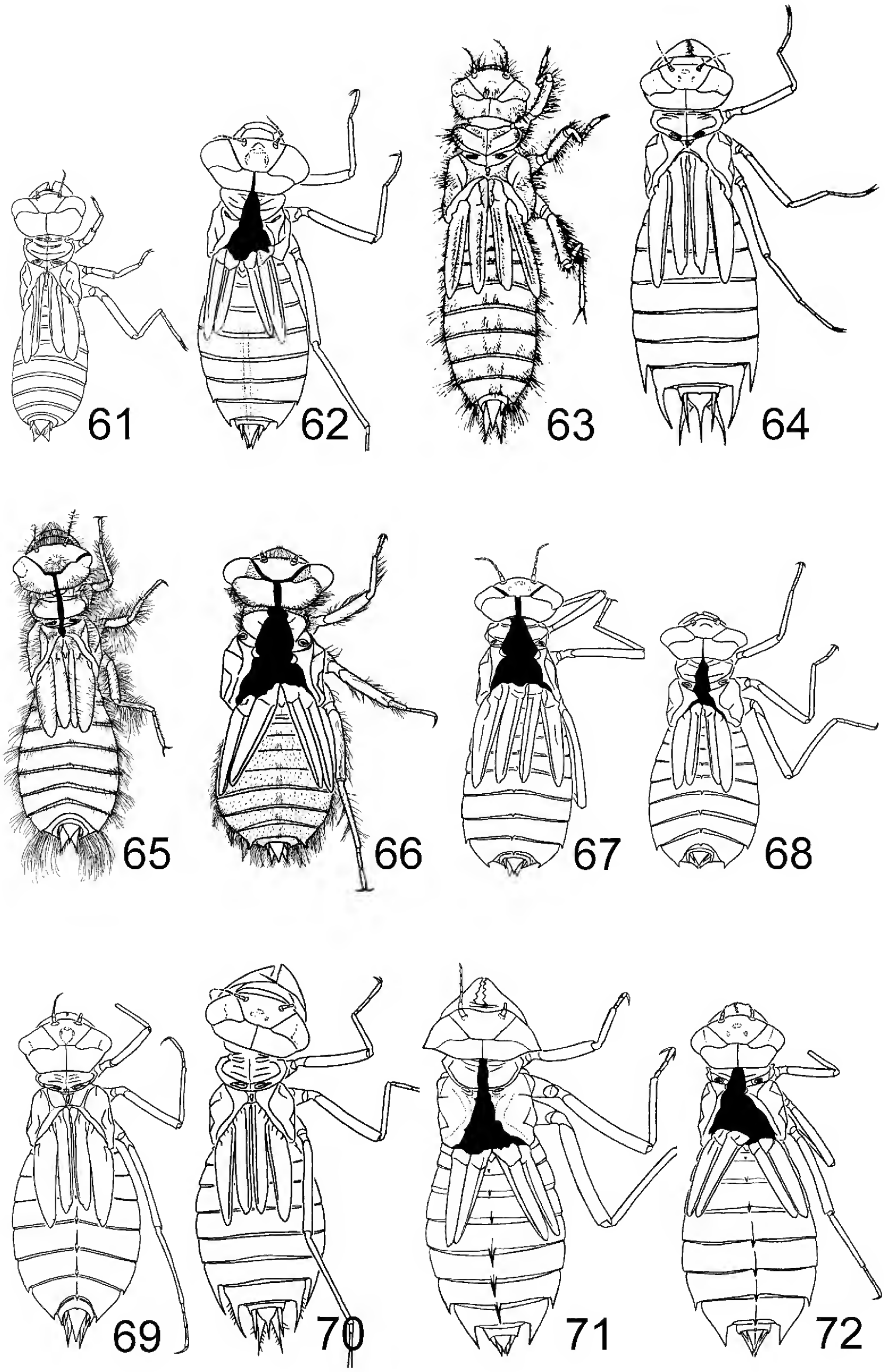
Larva not yet recognized. Genus monotypic.

Orthetrum balteatum Lieftinck, 1933

Hawking & Theischinger (2002); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009). The larva was identified by supposition only.

Orthetrum boumiera Watson & Arthington, 1978

Watson & Arthington (1978), with error as pointed out in Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009).



Figs 61-72. Final instar larvae of Australian Libellulidae: (61) *Nannophya* sp. (from Barcaldine); (62) *Neurothemis stigmatizans*; (63) *Orthetrum caledonicum*; (64) *Pantala flavescens*; (65) *Potamarcha congener*; (66) *Rhodothemis lieftincki*; (67) *Rhyothemis princeps*; (68) *Tetrathemis irregularis*; (69) *Tholymis tillarga*; (70) *Tramea stenoloba*; (71) *Urothemis aliena*; (72) *Zyxomma elgneri*.

Orthetrum caledonicum (Brauer, 1865)

Figs 63, 93

Tillyard (1916b, 1917b); Watson (1962); O'Farrell (1970); Watson & Arthington (1978); Hawking (1986, 1993, 1995); Watson & O'Farrell (1991), Hawking & New (1996); Hawking & Smith (1997); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Orthetrum migratum Lieftinck, 1951

Watson & Arthington (1978); Hawking (1993); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Larva not identifiable at present.

Orthetrum sabina (Drury, 1770)

Needham (1904); Watson & Arthington (1978); Hawking (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Orthetrum serapia Watson, 1984

Larva not yet recognized.

Orthetrum villosovittatum (Brauer, 1868)

Watson & Arthington (1978); Hawking (1986, 1993); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009).

*Genus ***Orthetrum*** Newman, 1833

Distributions confirm identifications on morphological basis from New South Wales and Victoria as *O. sabina* and *O. villosovittatum* and from north-western Australia as *O. migratum*. Larvae from northern Australia identified based on morphology as *O. sabina* may belong to either *O. sabina* or *O. serapia*. *O. caledonicum* can also be confidently identified if the larvae do not come from coastal south-eastern Queensland and coastal north-eastern New South Wales where *O. boumiera* occurs in dune situations (Theischinger 2007a).

Pantala flavescens (Fabricius, 1798)

Fig. 64

Cabot (1890), Lieftinck (1962); Watson (1962); Hawking (1993); Hawking & Ingram (1994); Hawking & Smith (1997); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of *Pantala* in Australia.

Potamarcha congener (Rambur, 1842)

Fig. 65

Kumar (1977); Van Tol (1992); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of *Potamarcha* in Australia.

Raphismia bispina (Hagen, 1867)

Larva not yet recognized. Sole species of *Raphismia* in Australia.

Rhodothemis lieftincki Fraser, 1954

Fig. 66

Hawking (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of *Rhodothemis* in Australia.

Rhyothemis braganza Karsch, 1890

Hawking (1993); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Rhyothemis graphiptera (Rambur, 1842)

Hawking (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Rhyothemis phyllis (Sulzer, 1776)

Lieftinck (1962); Hawking & Theischinger (1999); Theischinger (2000a, 2007a); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Rhyothemis princeps Kirby, 1894

Fig. 67

Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Rhyothemis resplendens Selys, 1878

Larva not yet recognized.

*Genus ***Rhyothemis*** Hagen, 1867

Larvae from tropical Queensland identified as either *R. braganza, R. graphiptera, R. phyllis* or *R. princeps* may belong to *R. resplendens* the larva of which is still undescribed, whereas *Rhyothemis* larvae collected outside of tropical Queensland can confidently be identified on morphology (Theischinger 2007a).

Tetrathemis irregularis cladophila Tillyard, 1908

Fig. 68

Theischinger & Fleck (2003); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of *Tetrathemis* in Australia.

Tholymis tillarga (Fabricius, 1798)

Fig. 69

Lieftinck (1962); Hawking (1993); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of *Tholymis* in Australia

Tramea eurybia Selys, 1878

Larva not yet recognized.

Tramea loewii Kaup, 1866

Tillyard (1917b, 1926); Hawking (1986, 1993), all as *Trapezostigma loewii*; Theischinger & Hawking (2003, 2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Tramea propinqua Lieftinck, 1942

Lieftinck (1962); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Tramea stenoloba (Watson, 1962)

Fig. 70

Watson (1962), Hawking (1993), both as *Trapezostigma stenoloba*; Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Larva not identifiable at present.

*Genus ***Tramea*** Hagen, 1861

Distributions confirm only identification of *Tramea* larvae from southern New South Wales and Victoria as *T. loewii*. *Tramea* larvae from north-eastern New South Wales may belong to either *T. loewii* or *T. eurybia*, from inland (including northern) and Western Australia either to *T. loewii* or *T. stenoloba*, whereas all four *Tramea* species may have to be considered in north-eastern Australia (Theischinger 2007a).

Urothemis aliena Selys, 1878

Fig. 71

Hawking (1993); Burwell & Theischinger (2003); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Sole species of the genus in Australia.

Zyxomma elgneri Ris, 1913

Fig. 72

Hawking (1993); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Zyxomma multinervorum Carpenter, 1897

Larva not yet recognized.

Zyxomma petiolatum Rambur, 1842

Lieftinck (1962); Hamada & Inoue (1985), not conforming to Lieftinck (1962); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

*Genus ***Zyxomma*** Rambur, 1842

The larva of *Z. multinervorum* is still unknown and non-conforming descriptive information is available for *Z. petiolatum*. All three species inhabit northern Queeensland and Northern Territory, but only *Zyxomma elgneri* occurs in southern Queensland, New South Wales and north-western Australia (Theischinger 2007a).

Genera Incertae Sedis

Nine genera clearly distinguishable on morphology; several very distinct units distinguishable but without general taxonomic recognition (Theischinger & Hawking 2006, under Gomphomacromiidae, Pseudocorduliidae, Austrocorduliidae, Cordulephyidae and Oxygastridae; Theischinger & Endersby 2009, under Gomphomacromiidae, Pseudocorduliidae, Austrocorduliidae and Cordulephyidae; Hawking *et al.* 2013).

Archaeophya adamsi Fraser, 1959

Fig. 73

Theischinger & Watson (1984); Hawking & Theischinger (1999); Theischinger (2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Archaeophya magnifica Theischinger & Watson, 1978

Theischinger (1978), as Gomphomacromiinae sp.; Williams (1980), as *Archaeophya*; Theischinger & Watson (1984); Hawking (1995); Theischinger (2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

*Genus ***Archaeophya*** Fraser, 1959

Identifications based on morphology can be confirmed by the widely disjunct distributions (Theischinger 2001a) . Tropical Queensland: *A. magnifica*; greater Sydney area: *A. adamsi*. (Theischinger et al. 2011)

Pseudocordulia circularis Tillyard, 1909

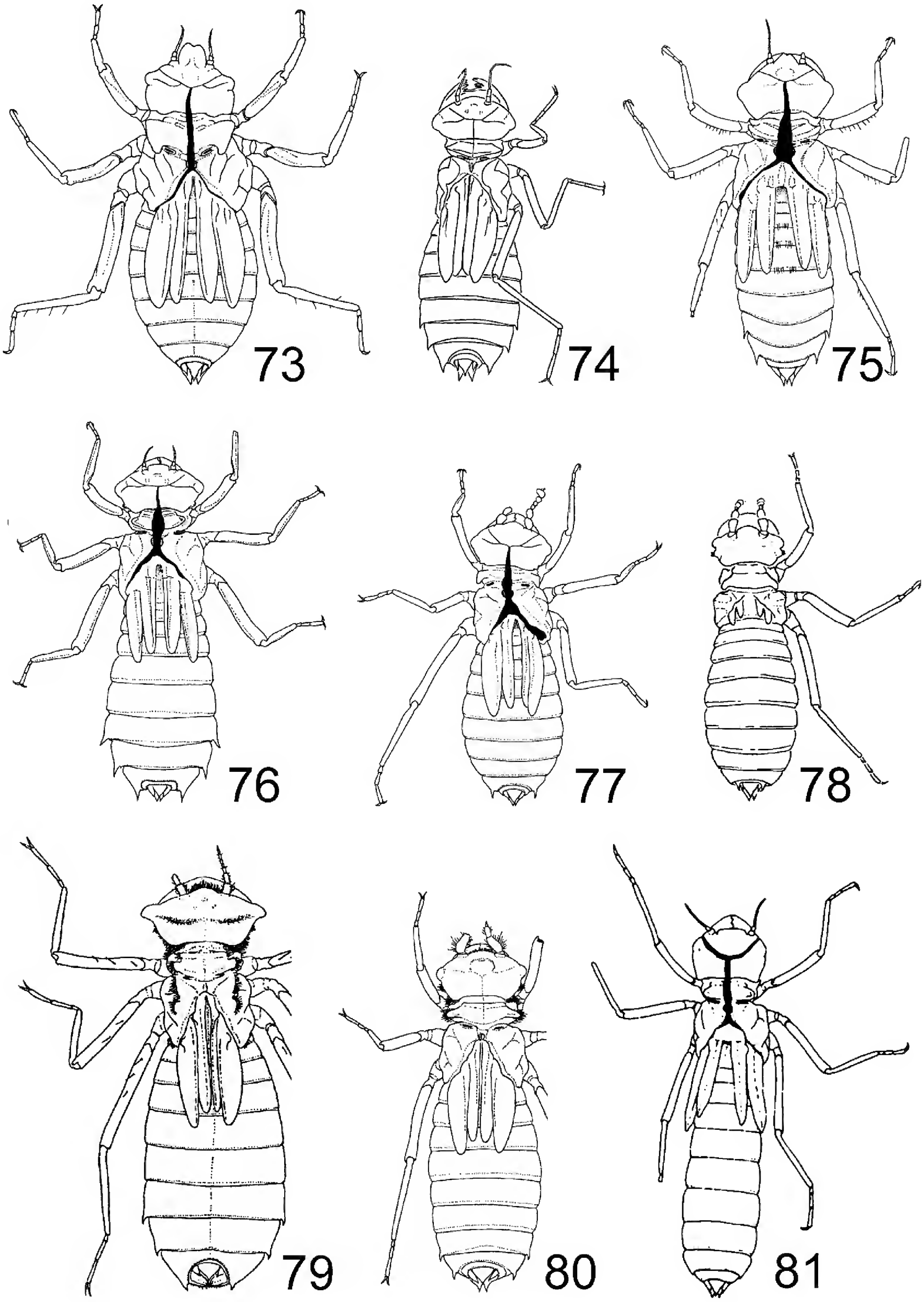
Fig. 94

Larva not identifiable/?available.

Pseudocordulia elliptica Tillyard, 1913

Fig. 94

Larva not identifiable/?available.



Figs 73-81. Final instar larvae of Australian Libelluloidea of genera *incertae sedis*: (73) *Archaeophya adamsi*; (74) *Cordulephya pygmaea*; (75) *Apocordulia macrops*; (76) *Austrocordulia leonardi*; (77) *Austrophya mystica*; (78) *?Austrophya* sp.; (79) *Hesperocordulia berthoudi*; (80) *Lathrocordulia metallica*; (81) *Micromidia convergens*.

*Genus ***Pseudocordulia*** Tillyard, 1909

Watson (1982), Theischinger & Watson (1984), Theischinger (2001a, 2010), Theischinger & Hawking (2006), Theischinger & Endersby (2009), Hawking *et al.* (2013), all as *Pseudocordulia* sp. The adults of the two *Pseudocordulia* species are extremely similar, and apparently the two species usually coexist (Theischinger & Watson 1978). Specific identification will probably be difficult even when larvae associated with adults of both species become available.

Cordulephya bidens Sjöstedt, 1917

Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Cordulephya divergens Tillyard, 1917

Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Cordulephya montana Tillyard, 1911

Tillyard (1911b, 1917b); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger (2007a); Theischinger & Endersby (2009).

Cordulephya pygmaea Selys, 1870

Fig. 74

Tillyard (1911b, 1914, 1916b, 1917b); Williams (1980), Hawking (1986); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger (2007a, 2010); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Cordulephya*** Selys, 1870

Cordulephya larvae identified from north of the Paluma-Eungella gap can be confirmed by distribution as *C. bidens*. *C. pygmaea* is probably the only species in Queensland south of the Paluma-Eungella gap (Theischinger 2007a). *C. pygmaea*, *C. divergens* and *C. montana* may coexist in south-eastern Australia and distinguishing *C. pygmaea* from *C. divergens/ montana* from there is difficult and often doubtful. Separating larvae of *C. divergens* and *C. montana* is not possible at present.

Apocordulia macrops Watson, 1980

Fig. 75

Theischinger & Watson (1984); Hawking (1986); Hawking & Theischinger (1999); Theischinger (2001a, 2009, 2010); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Theischinger *et al.* (2012, 2013); Hawking *et al.* (2013).

Genus monotypic.

Austrocordulia leonardi Theischinger, 1973

Fig. 76

Theischinger (1973, 2001a, 2010); Theischinger & Watson (1984); Hawking & Theischinger (1999); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Theischinger *et al.* (2009, 2013).

Austrocordulia refracta Tillyard, 1909

Tillyard (1910c, 1914, 1916b 1917b); Theischinger (1973, 1999, 2001a, 2010); Theischinger & Watson (1984); Hawking (1986); Hawking & Theischinger (1999); Theischinger & Hawking (2003, 2006); Theischinger & Endersby (2009); Theischinger *et al.* (2009).

Austrocordulia territoria Theischinger & Watson, 1978

Theischinger & Watson (1984); Hawking (1993); Theischinger (2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Austrocordulia*** Tillyard, 1909

A significant disjunction exists between the ranges of *A. territoria* (north of Northern Territory) and *A. leonardi* (eastern New South Wales). A disjunction also exists between the ranges of *A. territoria* and *A. refracta* (eastern Australia) which in eastern New South Wales coexists in places with *A. leonardi*. However, exclusive geographical ranges are not necessary for confident identifications of the three species (Theischinger 2001a).

Austrophya mystica Tillyard, 1909

Fig. 77

Theischinger & Watson (1984); Theischinger (2001a, 2010); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus possibly monotypic.

?Austrophya sp.

Fig. 78

Theischinger (2001a), as Genus “L”, species”m”.

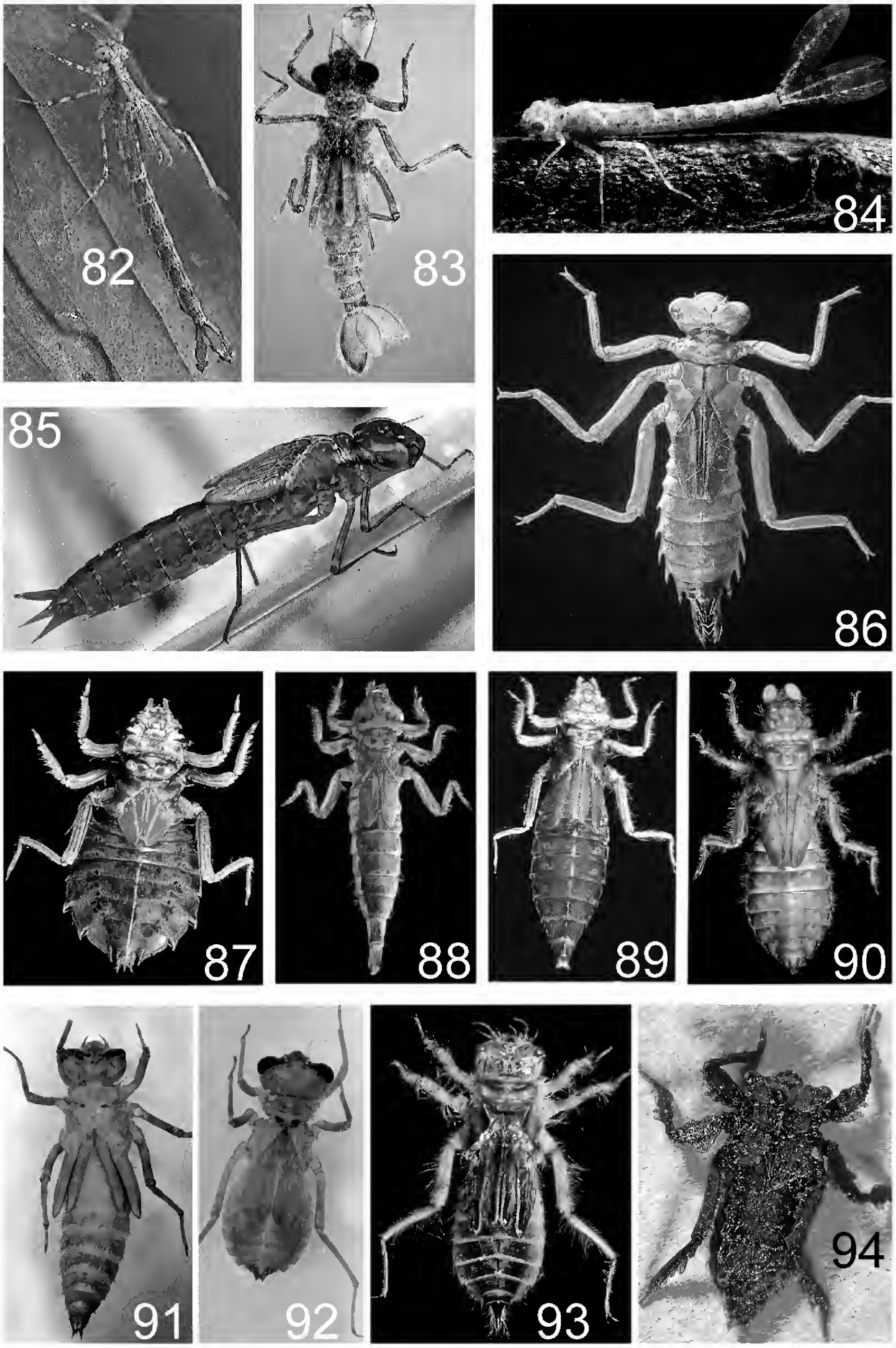
*Genus ***Austrophya*** Tllyard, 1909

There are marked morphological and size differences between *A. mystica* and *A.* sp. It is not considered certain that *A.* sp. is congeneric with *A. mystica*.

Hesperocordulia berthoudi Tillyard, 1911

Fig. 79

Ris (1910), as larva E; Watson (1962); Theischinger & Watson (1984); Theischinger (2001a, 2010); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013). Genus monotypic.



Figs 82-94. Larvae of Australian Odonata: (82) *Synlestes weyersii* (Synlestidae); (83) *Griseargiolestes intermedius* (Argiolestidae); (84) *Xanthagrion erythroneur*um (Coenagrionidae); (85, 86) Aeshnidae: (85) *Anax papuensis*; (86) *Notoaeschna sagittata*; (87- 90) Gomphidae: (87) *Ictinogiomphus australis*; (88) *Antipodogomphus acolythus*; (89) *Austroepigomphus (Xerogomphus) turneri*; (90) *Hemigomphus heteroclytus*; (91) *Eusynthemis virgula* (Synthemistidae); (92, 93) Libellulidae: (92) *Nannophya dalei*; (93) *Orthetrum caledonicum*; (94) *Pseudocordulia* sp. (Libelluloidea genera *incertae sedis*).

Lathrocordulia garrisoni Theischinger & Watson, 1991

Larva not available.

Lathrocordulia metallica Tillyard, 1911

Fig. 80

Watson (1962); Theischinger & Watson (1984); Theischinger (2001a, 2010); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

*Genus ***Lathrocordulia*** Tillyard, 1911

The significant disjunction between the ranges of *L. metallica* (south-western Australia) and *A. garrisoni* (tropical Queensland) should be sufficient to establish or support confident identification of the two species once the larva of *L. garrisoni* is discovered (Theischinger 2001a; Theischinger & Endersby 2009).

Micromidia atrifrons (McLachlan, 1883)

Theischinger (1978), as Gomphomacromiinae sp.; Theischinger & Watson (1984); Hawking & Theischinger (1999); Theischinger (2001a); Theischinger & Hawking (2006); Theischinger & Endersby (2009); Hawking *et al.* (2013).

Micromidia convergens Theischinger & Watson, 1978

Fig. 81

Theischinger & Watson (1984), as *Micromidia* "1"; Hawking & Theischinger (1999); Theischinger (2001a, 2010); Theischinger & Hawking (2006); Theischinger & Endersby (2009).

Micromidia rodericki Fraser, 1959

Larva not available.

*Genus ***Micromidia*** Fraser 1959

The island distribution (Thursday Island, Torres Strait) will most probably confirm the identification of the larva of *M. rodericki* once it is available (Theischinger 2001a). Distributional support is not needed to distinguish the larvae of the other two species. It appears that *M. atrifrons* is not present in southern inland Queensland, whereas there are no records of *M. convergens* from north-eastern Queensland (Theischinger & Endersby 2009).

Table 1. Australian odonate species and their larvae: original description, first descriptions of larva, confidence in identifications, supportive information

Taxon	OD	Ld	Au	IDR (*=for species, + =for group of species) based on				n	IDR	Total geographical range or, indicated by P, part of it where I based on M is reliable or supported
				M	G	g	e			
ORDER ODONATA	2 suborders clearly distinguishable on morphology									
SUBORDER ZYGOPTERA	8 families clearly distinguishable on morphology									
Family Hemiphlebiidae	**monotypic**									
Hemiphlebia mirabilis	1869	1928	Ti	*					*	
Family Synlestidae	**3 genera clearly distinguishable on morphology**									
Chorismagrion risi	1914	1956	Fr	*					*	
Episynlestes albicauda	1913	1993	Thea	+	*				*	**s and i Qld, ne NSW**
Episynlestes cristatus	1977	1956	Fr		*				*	**Qld N of P-E gap**
Episynlestes intermedius	1985	1993	Thea		*				*	**Qld: Eungella area**
Synlestes selysi	1917	1993	Thea	+	+	*			*	**P:** Qld: Eungella area
Synlestes weyersii	1869	1914	Ti			*			*	**P:** Qld: Carnarvon N.P., Victoria
Synlestes tropicus	1917	1993	Thea		*				*	**Qld: N of P-E gap**
Family Lestidae	**3 genera clearly distinguishable on morphology**									
Austrolestes aleison	1979	1962	Wa	+	*				*	**s WA**
Austrolestes psyche	1862	1917	Ti		*				*	**se A, SA**

Taxon	OD	Ld	Au	IDR (*=for species, + =for group of species) based on				n	IDR	Total geographical range or, indicated by P, part of it where I based on M is reliable or supported
				M	G	g	e			
Austrolestes minjerriba	1979	1999	HaTh	*	+				*	
Austrolestes annulosus	1862	1910	Ri	*					*	
Auslrolestes analis	1842	1906	Ti	*					*	
Austrolestes aridus	1908	1960	Li	*					*	
Austrolestes cingulatus	1839	1906	Ti	*					*	
Austrolestes io	1862	1960	Li	*					*	
Austrolestes leda	1862	1906	Ti	*					*	
Austrolestes insularis	1913				*			0	/	**most of n A**
Indolestes alleni	1913			?+	+			0		
Indolestes obiri	1979							0		
Indolestes tenuissimus	1906	1960	Li							
Lestes concinnus	1862	1960	Li	*					*	
Family Lestoideidae	**2 genera clearly distinguishable on morphology and size**									
Lestoidea barbarae	1967			? +	+			0		
Lestoidea brevicauda	1996							0		
Lestoidea conjuncta	1913	1956	Fr							
Lestoidea lewisiana	1996					*		0	/	**P:** Qld: Mt Lewis area
Diphlebia coerulescens	1913	1980	St	? +		*			*	**P:** Qld: Eungella area
Diphlehia euphoeoides	1907	1980	St		+					
Diphlebia hybridoides	1912	1980	St							
Diphlebia lestoides	1853	1909	Ti		+					
Diphlebia nymphoides	1912	1912	Ti			*			*	**P:** Qld: Carnarvon N.P.
Family Argiolestidae	**5 genera clearly distinguishable on morphology**									
Archiargiolestes parvulus	1977	1998	Th	+	+					
Archiargiol. pusillissimus	1925	1998	Th							
Archiargiolestes pusillus	1908	1962	Wa							
Austroargiolestes alpinus	1913			+	+			0		
Austroargiol. brookhousei	1986							0		
Austroargiolestes amabilis	1899							0		
Austroargiolestes aureus	1906	2006	ThHa							
Austroargiolestes calcaris	1958	1999	HaTh							
Austroargiolestes christine	1986							0		
Austroargiolestes chrysoides	1913	2006	ThHa							
Austroargiolestes elke	1986							0		
Austroargiolestes isabellae	1986	1995	Mu							
Austroargiolestes icteromelas	1862	1917	Ti							

Taxon	OD	Ld	Au	IDR (*=for species, + =for group of species) based on				n	IDR	Total geographical range or, indicated by P, part of it where I based on M is reliable or supported
				M	G	g	e			
Griseargiolestes albescens	1913	1999	HaTh	*	+				*	
Griseargiolestes bucki	1998	1998	Th	*					*	
Griseargiolestes eboracus	1913	1999	HaTh	*					*	
Griseargiolestes griseus	1862	1914	Ti	+		*			*	**P:** N and E from alpine region
Griseargiolestes intermedius	1913	1999	HaTh			*			*	**P:** alpine region
Griseargiolestes fontanus	1913						*	0		**E:** rain forest
Griseargiolestes metallicus	1917				*			0	/	**Qld N of P-E gap**
Miniargiolestes minimus	1908	1962	Wa	*					*	
Podopteryx selysi	1899	1978	WaDy	*			*		*	**E:** treeholes
Family Isostictidae	**8 genera clearly distinguishable on morphology**									
Austrosticta fieldi	1908	1993	Ha	+ ?	+	*			*	**P:** NT
Austrosticta soror	1917	1991	WaOF							
Austrosticta frater	1997					*		0	/	**P:** most of n Qld
Eurysticta coolawanyah	1969	1969	Wa	+ ?	*				*	**n WA: Pilbara area**
Eurysticta coomalie	1991	1993	Ha		+					
Eurysticta kununurra	1991	1993	Ha							
Eurysticta reevesi	2001				*			0	/	**n Qld**
Labidiosticta vallisi	1955	1999	HaTh	*					*	
Lithosticta macra	1991	1993	Ha	*					*	
Neosticta canescens	1913	1914	Ti		*				*	**se Qld, e NSW**
Neosticta fraseri	1991	2006	ThHa		+					
Neosticta silvarum	1917							0		
Oristicta filicicola	1913	1956	Fr	*					*	
Rhadinosticta banksi	1913	1993	Ha	*	+				*	
Rhadinosticta simplex	1901	1914	Ti	*		*			*	**P:** s Q, NSW, Vic
Selysioneura sp.		2009	Th	*					*	**Qld N of P-E gap;** Adults unknown
Family Platycnemididae	**1 genus distinguishable on morphology**									
Nososticta baroalba	1984			?+	+			0		
Nososticta coelestina	1906							0		
Nososticta fraterna	1933	1993	Ha							
Nososticta kalumburu	1984							0		
Nososticta koolpinyah	1984							0		
Nososticta koongarra	1984	1993	Ha							
Nososticta liveringa	1984							0		
Nososticta mouldsi	2000							0		
Nososticta pilbara	1969	1969	Wa							
Nososticta solitaria	1906							0		
Nososticta taracumbi	1984							0		
Nososticta solida	1860	1982	Nu			*			*	**P:** NSW, Vic

Taxon	OD	Ld	Au	IDR (*=for species, + =for group of species) based on				n	IDR	Total geographical range or, indicated by P, part of it where I based on M is reliable or supported
				M	G	g	e			
Family Coenagrionidae	**13 genera distinguishable on morphology, two of them difficult, larvae of one unknown**									
Aciagrion fragile	1906	1993	Ha	*					*	
Agriocnemis argentea	1906			?+	+			0		
Agriocnemis dobsoni	1954							0		
Agriocnemis kunjina	1969	2006	ThHa							
Agriocnemis rubricauda	1913							0		
Agriocnemis pygmaea	1842	1979	Al			*			*	**P:** NSW
Agriocnemis femina	1868	1962	Li		*				*	**n CY**
Archibasis mimetes	1913							0		no substitute species
Argiocnemis rubescens	1877	1917	Ti	*					*	
Austroagrion cyane	1876	1962	Wa	+	*				*	**s WA, SA**
Austroagrion watsoni	1982	1917	Ti		*				*	**se A** (excl. western Victoria)
Austroagrion pindrina	1969				*			0	/	**n WA: Pilbara area**
Austroagrion exclamationis	1915	1993	Ha	*					*	**ne and n A except Pilbara area**
Austrocnemis maccullochi	1926	1993	Ha	*					*	
Austrocnemis obscura	1991			?	*			0	/	**WA: Kimberley**
Austrocnemis splendida	1901	1917	Ti	+	*				*	**e A**
Austrocoenagrion lyelli	1913	1979	Al	*					*	
Caliagrion billinghursti	1901	1914	Ti	*					*	
Ceriagrion aeruginosum	1869	1936	Li	*					*	
Ischnura aurora	1865	1917	Ti	*	+				*	
Ischnura heterosticta	1839	1917	Ti	*					*	
Ischnura pruinescens	1906	1993	Ha	*					*	
Pseudagrion aureofrons	1906	1986	Ha	*	+				*	
Pseudagrion microcephalum	1842	1962	Li	*					*	
Pseudagrion ignifer	1906	2000	Th	*					*	
Pseudagrion lucifer	1997	2006	ThHa	*					*	
Pseudagrion cingillum	1869							0		
Pseudagrion jedda	1991							0		
Teinobasis rufithorax	1877			+				0	/	**ne Qld, CY;** id by substitution (*T. ariel*)
Xanthagrion erythroneurum	1876	1962	Wa	*					*	
SUBORDER ANISOPTERA	8 families + 1 group of genera incertae sedis clearly distinguishable on morphology									
Family Austropetaliidae	**2 genera clearly distinguishable on morphology**									
Archipetalia auriculata	1917	1979	Al	*					*	
Austropetalia annaliese	2013				*			0	/	**NSW N of Hunter River**
Austropetalia patricia	1910	1910	Ti	*	*				*	**NSW N of latitude ca 35º and S of Hunter River**
Austropetalia tonyana	1995	1986	Ha	*	*				*	**NSW S of latitude ca 35º, Vic**
Family Aeshnidae	**15 genera: 14 distinguishable on morphology and size, larvae of one undescribed;** several very distinct units distinguishable but without general taxonomic recognition									
Adversaeschna brevistyla	1842	1910	Ri	*					*	
Agyrtacantha dirupta	1889			+				0	/	**CY**

				IDR (*=for species, + =for group of species) based on						
Taxon	OD	Ld	Au	M	G	g	e	n	IDR	Total geographical range or, indicated by P, part of it where I based on M is reliable or supported
Anaciaeschna jaspidea	1839	2002	Th	*					*	
Anax georgius	1872	1987	WaTh	*					*	
Anax gibbosulus	1842	1987	WaTh	*					*	
Anax guttatus	1839	2002	Th	*					*	
Anax papuensis	1839	1916	Ti	*		*			*	**P:** WA W of Kimberley, c & s A
Austrogynac. heterogena	1908	1993	Ha	*					*	
Gynacantha dobsoni	1951	1916	Ti		+					
Gynacantha rosenbergi	1867	2007	Th	+						
Gynacantha kirbyi	1898			?				0		
Gynacantha mocsaryi	1898	1963	Fr	+						
Gynacantha nourlangie	1991	1993	Ha	*					*	
Dendroaeschna conspersa	1907	1914	Ti	*					*	
Acanthaeschna victoria	1901	2000	Th	*					*	
Antipodophlebia asthenes	1916	1980	WaTh	*					*	
Austroaeschna christine	1993	1993	Th	+	*				*	**Qld: Eungella area**
Austroaeschna ingrid	2008	2008	Th		*				*	**Vic: Grampians**
Austroaeschna multipunctata	1901	1982	Th		*				*	**NSW S of lat. ca 35ºS, most of Vic**
Austroaeschna sigma	1982	1982	Th		*				*	**se Qld; NSW N of lat. ca 34ºS**
Austroaeschna parvistigma	1883	1916	Ti				*		*	**E:** boggy and swampy habitats
Austroaeschna obscura	1982	1916	Ti	*					*	
Austroaesch. flavomaculata	1916	1982	Th	*					*	
Austroaeschna atrata	1901	1982	Th	*	+	*			*	**NSW and Vic: alpine region**
Austroaeschna subapicalis	1982	1916	Ti	*		*			*	**se Qld; NSW and Vic: N, S, E and W of alpine region**
Austroaeschna hardyi	1917	1979	Al	*	+				*	
Austroaeschna tasmanica	1916	1979	Al	*					*	
Austroaeschna anacantha	1908	1910	Ri	*	*				*	**s WA**
Austroaeschna cooloola	1991	1999	HaTh	+	*				*	**Qld: Cooloola area**
Austroaeschna pinheyi	2001	1982	Th		*				*	**si Qld**
Austroaeschna speciosa	1917	1982	Th		*				*	**Qld N of P-E gap**
Austroaeschna unicornis	1901	1916	Ti		*				*	**e A S of P-E gap & except Cooloola region**
Austroaeschna inermis	1901	1975	Th	*					*	
Austroaeschna eungella	1993	1993	Th	*	*				*	**Qld: Eungella a. & Clarke Ra.**
Austroaeschna muelleri	1982	1982	Th	*	*				*	**Qld: Carnarvon N.P.**
Austroaeschna pulchra	1909	1916	Ti	*	*				*	**much of e A**
Austrophlebia costalis	1907	1916	Ti	*	*				*	**e A: S of P-E gap**
Austrophlebia subcostalis	1996	1996	Th	*	*				*	**Qld: N of P-E gap**
Dromaeschna forcipata	1907	1982	Th	*	+				*	
Dromaeschna weiskei	1908	1982	Th	*					*	
Notoaeschna geminata	1982	1916	Ti	+	*				*	**se Qld, NSW N of Hunter River**
Notoaeschna sagittata	1901	1970	OF		*				*	**NSW S of Hunter River, Vic**

Taxon	OD	Ld	Au	IDR (*=for species, + =for group of species) based on				n	IDR	Total geographical range or, indicated by P, part of it where I based on M is reliable or supported
				M	G	g	e			
Spinaeschna tripunctata	1901	1975	Th	*	*				*	**NSW, Vic**
Spinaeschna watsoni	1982	1982	Th	*	*				*	**Qld: N of P-E gap**
Telephlebia brevicauda	1916	1970	OF	+	*				*	**NSW S of lat. ca 35º30’S, Vic**
Telephlebia cyclops	1916	1999	HaTh		*				*	**Qld S of P-E gap, ne NSW**
Telephlebia godeffroyi	1883	1916	Ti		*				*	**NSW N of lat. ca 35º30’S**
Telephlebia tillyardi	1916	2002	Th	+	*				*	**Qld: N of P-E gap**
Telephlebia tryoni	1917	2002	Th		*				*	**coastal se Qld and ne NSW**
Telephlebia undia	1985				*			0	/	**Qld: Carnarvon N. P.**
Family Petaluridae	**1 genus distinguishable on morphology**									
Petalura gigantea	1815	1909	Ti	+	*				*	**non-coastal se Qld, most of NSW**
Petalura litorea	1999	2000	Th		*				*	**coastal se Qld and ne NSW**
Petalura hesperia	1958	1958	Wa	*	*				*	**s WA**
Petalura ingentissima	1908	1998	An	*	+				*	**Qld: N of P-E gap**
Petalura pulcherrima	1913			*				0	/	specific status of *P. pulcherrima* still uncertain
Family Gomphidae	**7 genera clearly distinguishable on morphology; 2 subfamilies**									
Ictinogomphus australis	1873	1917	Ti	+	+	*			*	**P:** much of n and e A
Ictinogomphus paulini	1991							0		
Ictinogomphus dobsoni	1969	1998	Th		*				*	**WA: Pilbara area**
Antipodogomphus acolythus	1901	1917	Ti	+	+	*			*	**P:** NSW, Vic
Antipodogomphus dentosus	1991	1993	Ha							
Antipodogomphus edentulus	1991							0		
Antipodogomphus neophytus	1958	1993	Ha							
Antipodogomph. proselythus	1901	2007	Th							
Antipodogomphus hodgkini	1969	1998	Th		*				*	**WA: Pilbara area**
Armagomphus armiger	1913	1962	Wa	*					*	
Austroepigomph. praeruptus	1857	1998	Th	*		*			*	**P:** much of s Qld, NSW, Vic
Austroepigomphus gordoni	1962	1962	Wa	*	*				*	**WA, c A**
Austroepigomphus turneri	1901	1993	Ha	*	*				*	**n A**
Austrogomphus angelorum	1913						*	0		**E:** mature Murray River
Austrogomphus arbustorum	1906	1998	Th	+	*				*	**e Qld**
Austrogomphus pusillus	1917	2006	ThHa		*				*	**WA: Kimberley**
Austrogomphus mjobergi	1917	1993	Ha	*	*				*	**n Au**
Austrogomphus australis	1854	1986	Ha	+	*				*	**e A, SA**
Austrogomphus collaris	1854	1962	Wa		*				*	**s WA**
Austrogomphus cornutus	1991	1986	Ha	+	*				*	**i & se Qld, NSW, Vic, SA**
Austrogomphus doddi	1909				*			0	/	**ne Qld**
Austrogomphus guerini	1842	1970	OF	+	+	*			*	**P:** SA, Tas
Austrogomphus ochraceus	1869	1916	Ti							
Austrogomphus mouldsorum	1999				*			0		WA: Kimberley

Taxon	OD	Ld	Au	IDR (*=for species, + =for group of species) based on				n	IDR	Total geographical range or, indicated by P, part of it where I based on M is reliable or supported
				M	G	g	e			
Austrogomphus amphiclitus	1873	1998	Th	*	+	*			*	**P:** much of e and i Qld, NSW
Austrogomphus bifurcatus	1909	1998	Th	? +						
Austrogomphus divaricatus	1991							0		
Austrogomphus prasinus	1906	2006	ThHa							
Hemigomphus atratus	1991			+	+			0		
Hemigomphus comitatus	1909	1998	Th							
Hemigomphus theischingeri	1991	1998	Th							
Hemigomphus heteroclytus	1854	1910	Ti			*			*	**P:** si Qld
Hemigomphus gouldii	1854	1980	Wi							
Hemigomphus cooloola	1991	1998	Th	*			*		*	**Qld: Coolola area;** **E:** dune situations
Hemigomphus magela	1991	1993	Ha	*	*				*	**n NT**
Odontogomphus donnellyi	1991	1991	Wa	*					*	
Zephyromphus lateralis	1873	1962	Wa	*	*				*	**s WA**
Zephyrogomph. longipositor	1991	1998	Th	*	*				*	**Qld N of P-E gap**
Family Synthemistidae	**8 genera distinguishable on morphology, two of them difficult**									
Archaeosynthemis leachii	1871	1967	Wa	*	+				*	
Archaeosynth. occidentalis	1910	1962	Wa	*					*	
Archaeosynthemis spiniger	1913	1962	Wa	*					*	
Archaeosynthemis orientalis	1910	1910	Ti		*				*	**se A**
Austrosynthemis cyanitincta	1908	1962	Wa	*					*	
Choristhemis flavoterminata	1901	1910	Ti	*	+	*			*	**P:** e Au S of Daintree River
Choristhemis olivei	1909	2003	Th	*					*	
Eusynthemis barbarae	1985	2001	Th	+ ?	*				*	**Qld: Mt Lewis**
Eusynthemis tenera	1995							0		
Eusynthemis aurolineata	1913	1998	Th	*					*	
Eusynthemis rentziana	1998	1998	Th	*	+				*	
Eusynthemis tillyardi	1995	1910	Ti	*					*	
Eusynthemis guttata	1871	1995	Th	*					*	
Eusynthemis nigra	1906	1999	HaTh	*					*	
Eusynthemis deniseae	1977	1977	Th	*					*	
Eusynthemis brevistyla	1871	1986	Ha	*	+				*	
Eusynthemis virgula	1874	1986	Ha	*					*	
Eusynthemis netta	1999							0		**Qld: Mt Lewis area**
Eusynthemis ursa	1999			? +	*			0	/	**NSW: Barrington Tops**
Eusynthemis ursula	1998	2000	Th		*				*	**NSW: Chichester S.F.**
Parasynthemis regina	1874	1910	Ti	*			*		*	**E:** streams that dry to pools
Synthemiopsis gomphomacromioides	1917	2000	Th	*					*	
Synthemis eustalacta	1839	1910	Ti	*	*				*	**se A exc. Grampians, Tas and e SA**
Synthemis tasmanica	1910	1979	Al	*	*				*	**Vic: Grampians, SA, Tas**

Taxon	OD	Ld	Au	IDR (*=for species, + =for group of species) based on				n	IDR	Total geographical range or, indicated by P, part of it where I based on M is reliable or supported
				M	G	g	e			
Tonyosynthemis claviculata	1909	1998	Th	+	*				*	**Qld N of P-E gap**
Tonyosynthemis ofarrelli	1986	1998	Th		*				*	**se Qld, ne NSW**
Family Macromiidae	**1 genus distinguishable on morphology**									
Macromia tillyardi	1906	1993	Ha	*		*			*	**P:** e Qld ?except CY, ne NSW
Macromia viridescens	1911	2001	Th	*					*	
Family Corduliidae	**4 genera clearly distinguishable on morphology**									
Hemicordulia australiae	1842	1962	Wa	*					*	
Hemicordulia continentalis	1907	1999	HaTh	+	+					
Hemicordulia tau	1871	1914	Ti			*			*	**P:** WA, s & c A
Hemicordulia kalliste	1991				*			0	/	**extreme N of Au**
Hemicordulia flava	1991	2006	ThHa	*					*	**c A**
Hemicordulia intermedia	1871	1993	Ha	+	+	*			*	**P:** n, c and much of e A; WA except Pilbara area
Hemicordulia koomina	1969	2006	ThHa							
Hemicordulia superba	1911	1999	HaTh	*					*	
Metaphya tillyardi	1913			+				0	/	ident. by subst. (*M. elongata*)
Pentathemis membranulata	1890	1993	Ha	*					*	
Procordulia affinis	1871	1962	Wa	*	*				*	**s WA**
Procordulia jacksoniensis	1842	1970	OF	*	*				*	**e Au**
Family Libellulidae	**27 genera: 21 clearly distinguishable on morphology, larvae of 2 genera unknown**									
Aethriamanta circumsignata	1897	1993	Ha	+	+	*			*	**P:** NSW
Aethriamanta nymphaeae	1949	1993	Ha							
Agrionopt. insignis allogenes	1908	1993	Ha	*	+	*			*	**P:** NT, Qld S of P-E gap, NSW
Agr. longitudinalis biserialis	1879	2006	ThHa	*					*	
Austrothemis nigrescens	1901	1962	Wa	*					*	
Brachydiplax denticauda	1867	1993	Ha	+	+	*			*	**P:** Kimberley, NT, Qld S of P-E gap
Brachydiplax duivenbodei	1866							0	/	
Camacinia othello	1908			+				0	/	id by substitution (*C. gigantea*)
Crocothemis nigrifrons	1894	1962	Wa	*					*	
Diplacodes haematodes	1839	1914	Ti	*	+				*	
Diplacodes bipunctata	1865	1917	Ti	+		*			*	**P:** WA, c and s A
Diplacodes trivialis	1842	1962	Li							
Diplacodes melanopsis	1901	1986	Ha	*					*	
Diplacodes nebulosa	1793	1993	Ha	+						
Nannodiplax rubra	1868	1993	Ha			*			*	**P:** Kimberley
Huonia melvillensis	1998	2002	ThBr	*					*	
Hydrobasileus brevistylus	1865	1963	Fr	*					*	
Lathrecista asiatica festa	1879	2006	ThHa	*					*	identified by supposition
Macrodiplax cora	1867	1962	Li	*					*	

Taxon	OD	Ld	Au	IDR (*=for species, + =for group of species) based on				n	IDR	Total geographical range or, indicated by P, part of it where I based on M is reliable or supported
				M	G	g	e			
Nannophlebia eludens	1908	2006	ThHa	+	+					
Nannophlebia injibandi	1969	1993	Ha			*			*	**P:** Pilbara area
Nannophlebia mudginberri	1991	1993	Ha							
Nannophlebia risi	1913	1913	Ti			*			*	**P:** NSW, Vic
Nannophya australis	1865	1999	HaTh	*		*			*	**P:** most of ne A
Nannophya paulsoni	2003					*		0		
Nannophya sp.		2007	Th	*					*	**Qld: nr Barcaldine;** adults unknown
Nannophya dalei	1908	1979	Al	+	*				*	**se A**
Nannophya occidentalis	1908	1962	Wa		*				*	**s WA**
Neurothemis oligoneura	1867			?	+			0		
Neurothemis stigmatizans	1775	1962	Li	+		*			*	**P:** S of extreme n NT and CY
Notolibella bicolor	1977							0		
Orthetrum balteatum	1933	2002	HaTh	*					*	identified by supposition
Orthetrum boumiera	1978	1978	WaAr	+	+		*			**E:** dune situations
Orthetrum caledonicum	1865	1916	Ti			*			*	**P:** A except coastal se Qld and ne NSW
Orthetrum migratum	1951	1978	WaAr	+	+	*			*	**P:** Kimberley, Pilbara area
Orthetrum villosovittatum	1868	1978	WaAr			*			*	**P:** NSW, Vic
Orthetrum sabina	1770	1904	Ne	?	+	*			*	**P:** n WA and se A, i Qld
Orthetrum serapia	1984			+				0		
Pantala flavescens	1798	1890	Ca	*					*	
Potamarcha congener	1842	1977	Ku	*					*	
Raphismia bispina	1867							0		
Rhodothemis lieftincki	1954	1993	Ha	*					*	
Rhyothemis braganza	1890	1993	Ha	+	+	*			*	**P:** WA: Kimberley, n NT, se Qld
Rhyothemis resplendens	1878			?				0		
Rhyothemis graphiptera	1842	1993	Ha	*	+	*			*	**P:** Pilbara, c-Au
Rhyothemis phyllis	1776	1962	Li	*					*	
Rhyothemis princeps	1894	2006	ThHa	*					*	
Tetra. irregularis cladophila	1908	2003	ThFl	*					*	
Tholymis tillarga	1798	1962	Li	*					*	
Tramea eurybia	1878			+	+			0		
Tramea loewii	1866	1917	Ti			*			*	**P:** se NSW, Vic
Tramea propinqua	1942	1962	Li							
Tramea stenoloba	1962	1962	Wa							
Urothemis aliena	1878	1993	Ha	*					*	
Zyxomma elgneri	1913	1993	Ha	+ ?	+	*			*	**P:** s Qld, NSW. n-w Australia
Zyxomma multinervorum	1897							0		
Zyxomma petiolatum	1842	1962	Li							

Taxon	OD	Ld	Au	IDR (*=for species, + =for group of species) based on				n	IDR	Total geographical range or, indicated by P, part of it where I based on M is reliable or supported
				M	G	g	e			
Genera incertae sedis	**9 genera clearly distinguishable on morphology;** several very distinct units distinguishable but without general taxonomic recognition									
Archaeophya adamsi	1959	1984	ThWa	+	*				*	**se NSW**
Archaeophya magnifica	1978	1978	Th		*				*	**Qld N of P-E gap**
Pseudocordulia circularis	1909	1982	Wa	?+	+		*	?		**P:** terrestrial in rain forest leaf litter
Pseudocordulia elliptica	1913						*	?		
Cordulephya bidens	1917	2006	ThHa	+	*				*	**Qld N of P-E gap**
Cordulephya pygmaea	1870	1911	Ti		*				*	**mainland e A S of P-E gap**
Cordulephya divergens	1917	2006	ThHa	+	+					
Cordulephya montana	1911	1911	Ti							
Apocordulia macrops	1980	1984	ThWa	*					*	
Austrocordulia refracta	1909	1910	Ti	*		*			*	**P:** Qld, ne NSW, Vic
Austrocordulia leonardi	1973	1973	Th	*					*	
Austrocordulia territoria	1978	1984	ThWa	*	*				*	**n NT**
Austrophya mystica	1909	1984	ThWa	*	+				*	
***?Austrophya* sp.**		2001	Th	*					*	**Qld: Thornton Peak;** adults unknown
Hesperocordulia berthoudi	1911	1910	Ri	*					*	
Lathrocordulia garrisoni	1991			?	*			0	/	**Qld N of P-E gap**
Lathrocordulia metallica	1911	1962	Wa	+	*				*	**s WA**
Micromidia·atrifrons	1883	1978	Th	*	+	*			*	**P:** ne Qld, CY
Micromidia convergens	1978	1984	ThWa	*					*	
Micromidia rodericki	1959				*			0	/	**Thursday Island**

Abbreviations used in the table. General terms: OD=year of original description of adult; Ld=first description/descriptive detail of larva; Au=author/s of Ld; M=morphological disparity; G=distributional disparity; g=partial distributional disparity; e=ecological particular; n=larva not available (given by 0); IDR=reliable Identification possible. Geographical terms: A=Australia; CY=Cape York Peninsula; e=eastern; i=inland; n (in table head)= no descriptive information available at the present time (indicated by 0); n (in distribution column) northern; N=north; ne=north-eastern; P-E gap=Paluma-Eungella gap; s=southern; S=south; se=south-eastern; NG=New Guinea; NSW=New South Wales; NT=Northern Territory; Qld=Queensland; SA=South Australia; si=southern inland;WA=Western Australia; Vic=Victoria. Distributional data are included only with species for which these details markedly improve the reliability of identification. Authors: Al=Allbrook; An=Andress; Ca=Cabot; Fr=Fraser; Ha=Hawking; HaTh=Hawking & Theischinger; Ku=Kumar; Li=Lieftinck; Mu=Murray; Ne=Needham; Nu=Nuttall; OF=O'Farrell; St=Stewart; Th=Theischinger; Thea=Theischinger *et al.;* ThBr=Theischinger & Brown; ThFl=Theischinger & Fleck; ThHa=Theischinger & Hawking; Ti=Tillyard; Wa=Watson; WaAr=Watson & Arthington; WaDy=Watson & Dyce; WaOF= Watson & O'Farrell; WaTh=Watson & Theischinger; Wi=Williams.

Geographical range or part of is only given if it markedly effects the reliability of identification. Full geographical ranges are written in **bold**; part of the range for which reliable identification is written in normal subsequent to **P:**.

Some species are, within their genus, not listed in alphabetical order to better show morphological or geographical mutualities by the symbol + in cells 'merged' down the subcolumns M and G of column IDR.

Reasonably reliable identifications can be achieved at least for part of their ranges for 235 of the 325 species if the individuals to be identified are in good shape and close to final instar, and if their origin is known. Of these 215 are marked in column IDR by the symbol *, the remaining 20 by the symbol /. Identifications for 90 of the 325 species are at present hardly possible and therefore not marked with any symbol in the column IDR. Should larvae be identified as belonging to a species without an icon in the column IDR, it is strongly recommended that the details be thoroughly checked by repeating the identification procedure.

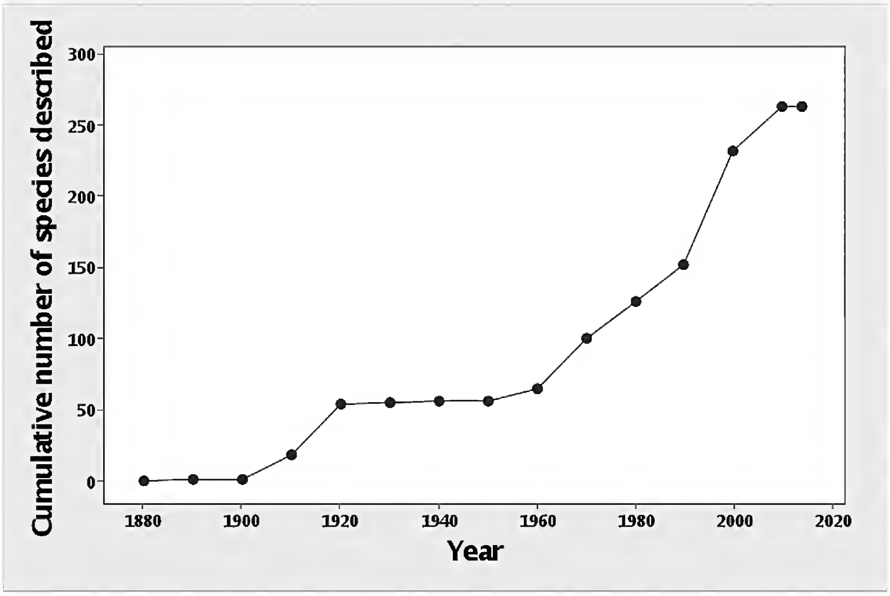


Figure 95. Accumulation curve illustrating the increase in descriptive information for Australian odonate larvae between 1880 and 2014.

Conclusions and outlook

This compilation of the information regarding Australian dragonfly larvae and the possibility for accurate identification provides some interesting results. Of 325 Australian Odonata species, larvae are known for 263 species, or about 80% of the total fauna. No descriptive information is available for the larvae of 62 species (marked with the symbol 0 in column n of Table 1).

Reliable identifications, based on morphology alone are possible for 136 species, an additional 47 species can be identified reliably using a combination of morphological and distributional data. On top of that identifications of 30 more species are reliable within particular parts of their ranges, and one more can be identified based on its ecology. Considering these factors, it should also be possible to reliably identify another 20 species once their larvae are available.

The larvae of four Australian dragonfly genera, *Archibasis*, *Camacinia*, *Notolibellula* and *Raphismia* are unknown or undescribed.

These numbers show that the ratio 'Number of identifiable species/Total number of species' is markedly higher for Anisoptera (170/214) than for Zygoptera (64/111) and makes the Platycnemididae, Lestoideidae and Argiolestidae (in that order) the families for which progress in larval taxonomy is most urgently needed. This is of course also a reflection of the larval taxonomic difficulties of these groups. To improve the situation remains a big challenge for identification certifiers and taxonomists and would also make, perhaps in connection with more applied and timely issues, great topics for regional or Australia-wide PhD studies. Also DNA-matching of adults and larvae/exuviae will be a powerful method of confirming identifications in future.

Table 2. Distribution of knowledge sufficient for specific identifications across families

Family	**Species identifiable**	**Total species**	**Ratio**
Platycnemididae	1	12	0.08
Lestoideidae	3	9	0.33
Argiolestidae	8	22	0.36
Gomphidae	23	38	0.61
Isostictidae	11	16	0.69
Libellulidae	40	57	0.70
Coenagrionidae	23	30	0.77
Lestidae	11	14	0.79
Lib. incertae sedis	16	20	0.80
Corduliidae	10	12	0.83
Aeshnidae	46	50	0.92
Synthemistidae	24	26	0.92
Hemiphlebiidae	1	1	1.00
Synlestidae	7	7	1.00
Austropetaliidae	4	4	1.00
Petaluridae	5	5	1.00
Macromiidae	2	2	1.00
Total	**235**	**325**	**0.72**

Summary

This paper summarises the morphological and geographic information for the larvae of all species of Australian dragonflies. We present an annotated checklist giving all known references which provide information on the identification characters of each species. For each genus that includes more than one species there is a paragraph which discusses if species can already, or cannot yet, be distinguished on morphological characters. We also include information on whether, and under which conditions, geographic locality helps or is enough to make a diagnosis. A table provides the year of original description and of first description of the larva of each species. It also indicates the level of confidence of identifications from available keys and other supportive information. The paper is fully referenced and includes, for more than 70% of the Australian dragonfly genera, illustrations of final stage larvae or exuviae ("shells").

We wrote this paper to improve the reliability of identification of the larvae of Australian species of dragonflies. It brings together references to all available information on the identification of larvae of any Australian dragonfly species. This encourages access to original sources and to confirm results of identifications by using several ways of diagnosing when in doubt. In particular it emphasizes the geographical aspect of making identifications. Geographical information can improve confidence of inconclusive morphological identifications of larvae by reducing the number of possible options and improves the chances for reliable identification of even relatively early larval stages. Identifications are only valuable if they are accurate and reliable, so the paper will be helpful in many current issues including biodiversity, conservation, river health, climate change and others.

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A reassessment of the pycnogonid genus *Stylopallene* (Arthropoda, Callipallenidae) with description of a new genus

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Abstract Staples D.A. 2014. A reassessment of the Pycnogonid Genus *Stylopallene* (Arthropoda, *Callipallenidae*) with description of a new genus. *Memoirs of the Museum of Victoria* 72: 121-129.

The genus *Stylopallene* comprising only four species is reviewed. All species are recorded from Australia, predominantly from the southern and south-eastern coastlines in association with arborescent bryozoans. Sexual dimorphism in the scape segments is recognized in the genus for the first time. The status of *Stylopallene dorsospinum* is re-evaluated and assigned to the new genus *Bamberene*. A diagnosis of the new genus is provided along with additional images to complement existing figures.

Keywords Callipallenidae, *Stylopallene*, *Bamberene*, southern Australia, Western Port, pycnogonid, arborescent bryozoans

Introduction

This is the second paper reviewing the family Callipallenidae. The first paper summarized the systematic position of the family and reviewed the genus *Pseudopallene* (Staples, 2014). In this paper the genus *Stylopallene* (Clark, 1963) is reviewed.

The genus *Stylopallene* was erected by Clark (1963) to accommodate several specimens from Port Arthur, southern Tasmania. The type species of the genus is *S. cheilorhynchus* Clark, 1963. In the same paper Clark described *S. dorsospinum* Clark, 1963 and *S. tubirostris* Clark, 1963 both recorded from localities off the New South Wales coastline. Stock (1973a) recorded a fourth species, *S. longicauda* Stock, 1973a from Western Port, Victoria. *Stylopallene cheilorhynchus, S. longicauda* and *S. tubirostris* share a smooth, oval trunk; similarly shaped chela with fingers much shorter than the palm; eight eye lenses; sexually dimorphic scape segments and the presence of an oviger claw. These species are associated with arborescent bryozoans predominantly belonging to the genus *Amathia* Lamouroux, 1812. Since the recent introduction of the seasonally abundant bryozoan *Zoobotryon* sp. (possibly *Z. verticillatum*) into Western Port, Victoria, *S. longicauda* has also been associated with that genus. Juveniles are carried by the adult male presumably until they reach the stage of independence (fig. 2C). All three species are active swimmers (fig. 2E, F). Other species wait description.

Proximolateral processes found on the chelifore scapes of all female *Stylopallene* are grasped by the male chelae and serve as anchoring points during the mating process (fig. 2D). These processes do however appear to have a structure more complex than simply folds in the cuticle to be grasped by the male and I suspect that their full function is still to be resolved (fig. 3C, H). Similar processes or nodes are recorded on the chelifore scapes of *Cheilopallene nodulosa* (Hong and Kim, 1987) and were suspected by Nakamura and Child (1991) to be indicators of sexual dimorphism.

Stylopallene dorsospinum does not accord with the accepted concept of *Stylopallene*. The trunk is extremely compact, almost circular in outline and with tall mid-dorsal trunk processes. The cephalon is shorter than the remainder of the trunk and there is no obvious neck. There are four eyes only; the chela palm is much shorter than the fingers; the female scape shows no evidence of sexual dimorphism, and the oviger claw is absent.

In the absence of a terminal claw on the ovigers, *S. dorsospinum* conforms to the diagnoses of *Callipallene* Flynn, 1929, *Pallenoides* Stock, 1951 and *Austropallene* Hodgson, 1915. In these genera the trunk is elongate with clearly-spaced lateral processes that do not conform to the compact, inflated and almost circular shape of *S. dorsospinum*. The highly developed dorsal trunk processes, the tapering proboscis with protruding jaws and gaping, smooth chela fingers of *S. dorsospinum* have no counterpart in *Callipallene* and *Pallenoides*. Auxiliary claws are always present and well developed in *Callipallene* whereas in *Pallenoides* they may be absent, small or vestigial but the fan-shaped oviger spines in *Pallenoides* are characteristic of that genus. *Stylopallene dorsospinum* substantially agrees with the diagnosis of

Austropallene; in particular with *Austropallene cristata* (Bouvier, 1911) with which it shares the robust mid-dorsal trunk processes. It also shares a strongly tapered proboscis with *A. tibicina* Calman, 1915. Interestingly both these species are recorded from the Campbell Plateau in far southern New Zealand waters and are geographically closest to the recorded distribution of *S. dorsospinum*. Possession of femoral cement glands is shared with *Austropallene* but no species shares the compact, almost circular body shape with *S. dorsospinum* or chelifore fingers which are conspicuously longer than the palm. The chelifore scapes of *S. dorsospinum* are carried directly in front of the cephalon and the chelae are directed slightly outward from the midline of the scapes. In all species of *Austropallene* the chelifore scapes are directed away from the midline and the chelae face inward to transverse the front of the proboscis. The oviger spines in *Austropallene* are numerous and distinctly compound whereas in *S. dorsospinum* they tend to be few in number variably developed. The Antarctic and sub-Antarctic distribution records of *Austropallene* are also inconsistent with the temperate water records of *S. dorsospinum*. So far as I am aware the presence of male genital pores on all legs of *S. dorsospinum* is unique within the family.

Stylopallene dorsospinum cannot be accommodated in any existing genus in the family Callipallenidae and a new genus *Bamberene* is proposed.

As a consequence of this ongoing family review, the necessity to modify generic diagnoses is evident. The status of specimens assigned to species *incertae sedis* will need to be resolved and in some cases this may only be accommodated by the erection of additional genera.

A generic key is deferred pending the unraveling of these taxonomic issues.

Materials and methods

Comparative material was sourced from the Australian Museum (AM), Museum Victoria (NMV) and the author's private collection.

Unless stated otherwise, terminology and measurements are as defined by Fry and Hedgpeth 1969.

Reference to the neck region of the cephalon refers to the narrow section between the anterior margin of the first lateral processes and the base of the distal inflated part or crop.

The length of the trunk is measured from the anterior margin of the cephalon to the tip of a fourth lateral process.

Leg span represents the sum of individual leg segments of the third pair of legs plus the width of the trunk measured across the second lateral processes. Measurements are derived from the original descriptions of the type specimens and adjusted where necessary in the light of additional material. The leg span should be regarded as an approximation of a typical specimen.

Photographs of live specimens were taken *in situ* by the author. Preserved specimens were photographed by the author using a Leica DM5000 B compound microscope and a Leica DC500 camera with montage software.

For the purpose of this paper, the term 'larvae' describes individuals still attached to the male ovigers and 'juvenile' to those unattached individuals with incompletely developed legs.

The term 'swimming' refers to the vigorous treading action that lifts the specimen into the water column thenceforth to be carried by the currents.

The term 'lips' appears to have been first introduced by Stock, 1955 to describe the projecting mouth parts of the genus *Cheilopallene* (*Cheilos*: lip) and was again used by Clark (1963) in his diagnosis of *Stylopallene*. In neither genera are the lips attached to, nor do they surround, any other structure that could otherwise be defined as jaws in which case the lips are simply modified jaws. A more appropriate description would perhaps have been 'lip-like' jaws. The term 'jaws' is used throughout this paper to describe the three antimeres surrounding the mouth opening.

Callipallenidae Hilton, 1942

Stylopallene Clark, 1963

Diagnosis (modified from Clark, 1963). Trunk robust, compact, smooth, ovoid. Cephalon well developed, length about equal to remainder of trunk, neck broad, hardly narrowing throughout. Lateral processes touching or almost touching, separated from central inflated part of the trunk by a transverse suture. Ocular tubercle low, rounded, wider than tall and placed on posterior half of cephalon. Eight eyes, arranged in four groups of two. Proboscis glabrous, with a broad cylindrical basal part tapering to a narrow, short or long tubular distal part separated by a transverse cuticular suture. Jaws tripartite, projecting, pointed, glabrous. Abdomen fusiform, broad or slender, not reaching beyond the end of coxa 1 of leg 4. Palps absent. The orientation of the chelifores follows the curvature of the trunk, chelifore scape one-segmented, female with proximolateral process on each scape. Chela fingers held in prolongation with the palm, shorter than palm, curved, gaping when closed, non-denticulate, immoveable finger blunt, rounded throughout, without defined chitinous cutting edge, moveable finger pointed, both fingers contorted in early juvenile stages. Ovigers ten-segmented in both sexes, terminal claw non-denticulate or with single tooth, distal apophysis on fifth segment in male globular, strigilis spines weakly denticulate. Legs stout, smooth, propodus curved, with well-defined heel. Auxiliary claws absent. Femoral cement gland ducts absent. Genital pores on ventral surface of coxa 2 on all legs of female, legs 3 and 4 of male.

Type species. *Stylopallene cheilorhynchus* Clark, 1963.

Stylopallene cheilorhynchus Clark, 1963.

Figurel A-F

Stylopallene cheilorhynchus. Clark, 1963: 36-38—Stock, 1973a: 117—Stock, 1973b: 92—Staples, 1997: 1055—Staples, 2005: 166-168—Arango and Brenneis, 2013: 430

Remarks. The leg span is about 20 mm. The segmentation between trunk segments 3 and 4 is present but indistinct. The first two pairs of lateral processes are often more widely separated than the others, processes 2-4 are touching throughout most of their length or narrowly separated. The length of the narrow distal part of the proboscis is about 40% of the basal part. The abdomen is short, broad, shield-shaped and directed slightly downward. A depression at the base of the abdomen gives the impression that it is segmented and possibly accounts for Clark's illustration of a segmentation line (Clark, 1963, fig. 19A). The oviger spines are variable and irregular in shape; the spine teeth are generally poorly developed. The terminal claw is strong, about one-third the length of segment 10 and with a slightly irregular inner margin but without teeth.

A piece of a fragmented exuvia shows that the trunk separates around the lateral ecdysial line and that the dorsal

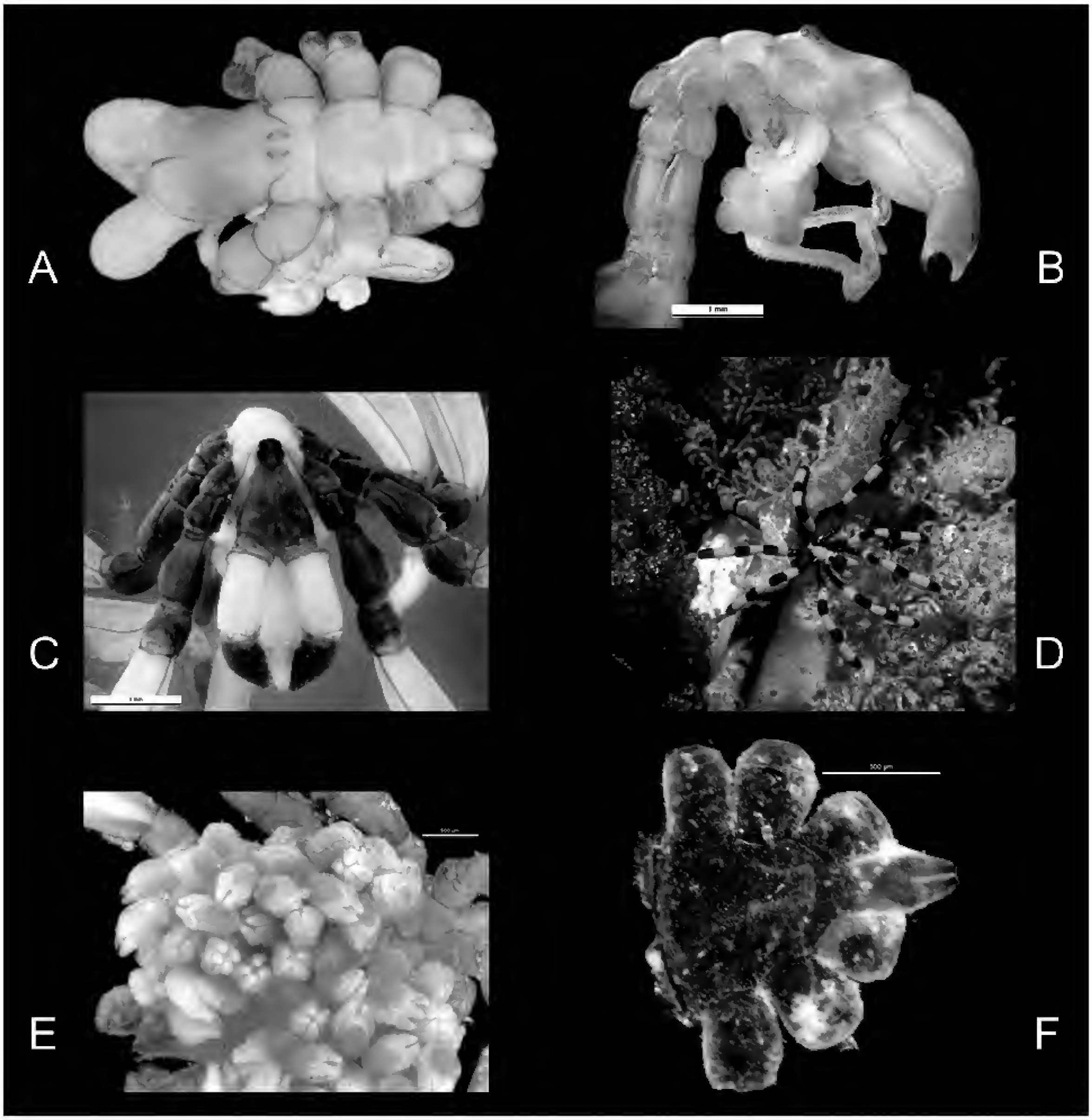

Figure 1. *Stylopallene cheilorhynchus*, A, B, male, dorsal and lateral views of trunk; C, female, anterior view; D, live specimen; E, protonymphon on ovigers; F, discarded exuvia.

surface of the trunk is discarded inclusive of the lateral processes and abdomen. The transverse suture that divides the trunk from the lateral processes remains intact. The abdomen does not separate into dorsal and ventral components (fig. 1F).

This species is most-often recorded in association with *Amathia wilsoni* Kirkpatrick, 1888. Specimens are present in large numbers seasonally with fertile specimens commonly observed from November to April in water temperatures of 15-26 degrees centigrade and less frequently at other times of the year. Fifty-two protonymphon which probably represents more than one mating event have been recorded from a single oviger. Ovigerous and larvae-bearing males together with juveniles at various stages of development are recorded from the same bryozoan colony. Juvenile chela fingers are slender, distorted of the form described by Staples (2005 figs. 5B).

Body markings. Specimens are usually described as being 'banded'. The abdomen, central region of trunk and proboscis are typically cream; lateral processes are dark. The cephalon is mostly dark dorsally, widening from the ocular tubercle to the base of the chelifores. The chelifore scapes are light and the chelae black. The distal half to one-third of the femur and tibiae are black, tarsus black, dorso-distal surface of propodus black and claw light. Distal oviger segments black. The light colour may vary slightly from cream to yellow or with a slightly green tinge.

Stylopallene cheilorhynchus is widely distributed and often recorded along the southern Australian coastline.

Distribution. Southern New South Wales to southern Western Australia and Tasmania at 1.0 to 90 m depth.

Stylopallene longicauda Stock, 1973

Figures 2 A-D

Stylopallene longicauda. Stock, 1973a: 117-119—Staples, 1997: 1055—Sherwood et al, 1998

Remarks. The leg span is typically about 30 mm. Although not recorded by Stock, the segmentation line between trunk segments 3 and 4 is present but often obscure. The first and second pairs of lateral processes are usually more widely spaced than the remainder which are touching at their bases and narrowly separated distally. The transverse suture line in the cuticle that separates the proximal part of the proboscis from the tapered distal part was not illustrated by Stock (1973a, fig. 8b). The distal portion of the proboscis is about one-third the length of the basal part. The abdomen ranges from horizontal to slightly inclined. The oviger spines are strongly curved distally and have several irregular denticulations as illustrated by Stock (1973a, fig. 8g). The terminal claw is robust, smooth and curved inwards distally. A small tooth is variably present on the inner margin of the claw at about the point of curvature but in the specimens examined there is no evidence of a tooth on the outer margin as illustrated by Stock (1973a, fig. 8f). One or two tiny crenulations may follow the main tooth. Thirty to forty eggs are carried on each male oviger. This species is most often recorded in association with the bryozoan *Amathia biseriata* Krauss, 1837.

Stylopallene longicauda and *S. cheilorhynchus* are remarkably similar with identical colour patterns. The most conspicuous difference is evident in the legs and abdomen of *S. longicauda* which are longer and more slender. Little else differentiates the two species.

Analysis of seventy-nine specimens of *S. longicauda* collected from a single bryozoan colony in Western Port revealed only one exception to the otherwise consistent colour pattern. Records of *S. longicauda* outside of Western Port are rare.

Distribution Western Port, central Victoria.

Stylopallene tubirostris Clark, 1963

Figures 3A-H

Stylopallene tubirostris. Clark, 1963: 40-42—Child, 1975: 15-16—Staples, 1997: 1055—Bamber, 2005: 334—Arango and Brenneis, 2013: 431
Siphopallene tubirostris Stock, 1968: 45-46
Siphopallene tubirostrum Stock, 1973b: 96

Remarks. The leg span is typically about 25 mm. The lateral processes are either touching or narrowly separated at their bases. The first and second processes are often more widely spaced than the remainder. Clark (1963) recorded the length of the cephalon as being equal to the remaining three segments but in the specimens examined the cephalon is clearly longer (fig. 3A). The syringe-like distal part of the proboscis is about as long as the basal part and terminates in three short, chitinous jaws. The abdomen is longer and narrower than figured by Clark (1963 fig. 21 A). The oviger spines are variably compound with 4-5 teeth mainly confined to the upper margin. One male examined carried 15 eggs on a single oviger.

This species has been recorded on the arborescent bryozoans *Amathia tortuosa* Tenison-Woods, 1880 and *A. woodsi* Goldstein, 1879.

Anecdotal evidence suggests that this species is most common in eastern Victoria and southern New South Wales.

Distribution. Yanchep Reef, Esperance Bay, Western Australia to Coffs Harbour, New South Wales and Bass Strait, Tasmania. Tide pools to 65m depth.

Discussion. The body markings of *S. tubirostris* are much the same as in *S. longicauda* and *S. cheilorhynchus* but distinguished by a black shoulder band or saddle that runs through the ocular tubercle and by the dark chelifore scapes (fig. 3A, E). The cephalon is otherwise a pale colour. By and large the markings are constant and provide a useful initial diagnostic character.

Along with other species of *Stylopallene* some specimens have been described as having a pink tinge although this can often be attributed to epiphytic coralline algae (fig. 3E).

Genus *Bamberene* gen. nov.

Zoobank LSID. http://zoobank.org/urn:lsid:zoobank.org:act:BF93B44B-479D-4DD3-BE50-2453D872F74A

Diagnosis. Trunk, compact, ovoid, mid-dorsal processes tall, prominent, segmentation distinct, lateral processes and legs with numerous spiniform projections, cephalon shorter than remainder of trunk, carried horizontally, neck constricted. Dorsal swellings over bases of chelifore insertions bulbous, occupying entire cephalon forward of the ocular tubercle. Lateral processes in contact throughout length, separated from the central trunk region by transverse suture lines. Ocular tubercle taller than wide, placed on posterior half of cephalon. Four eyes. Distal half of proboscis tapering to narrow tip, basal half inflated with slight mid-constriction, the two halves transition seamlessly. Abdomen fusiform, inflated in mid-

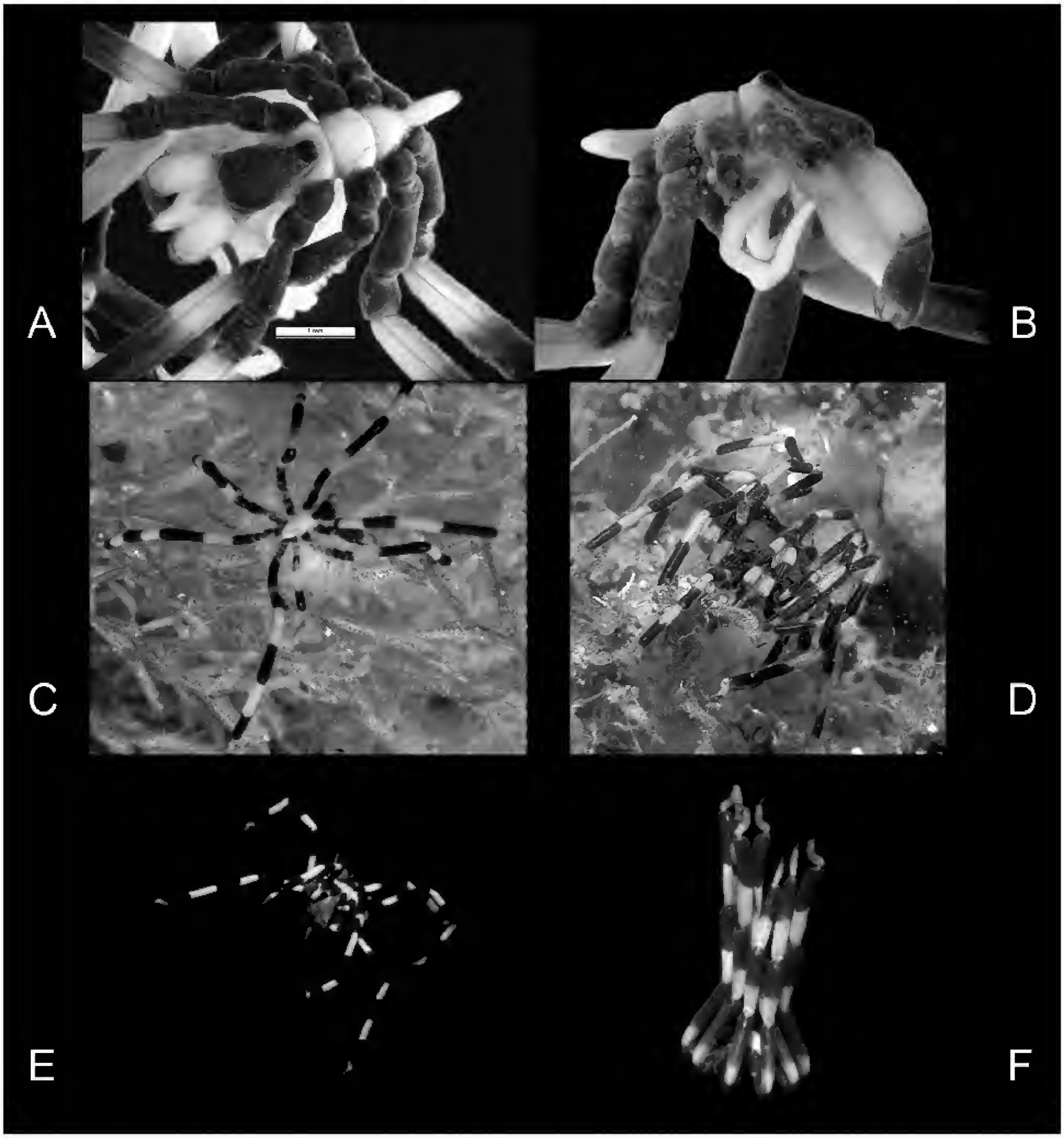

Figure 2. *Stylopallene longicauda*, A, B, male dorsal and lateral views of trunk; C, male carrying juveniles, D, mating pair, male dorsal; E, swimming; F, plummeting on completion of the swimming phase.

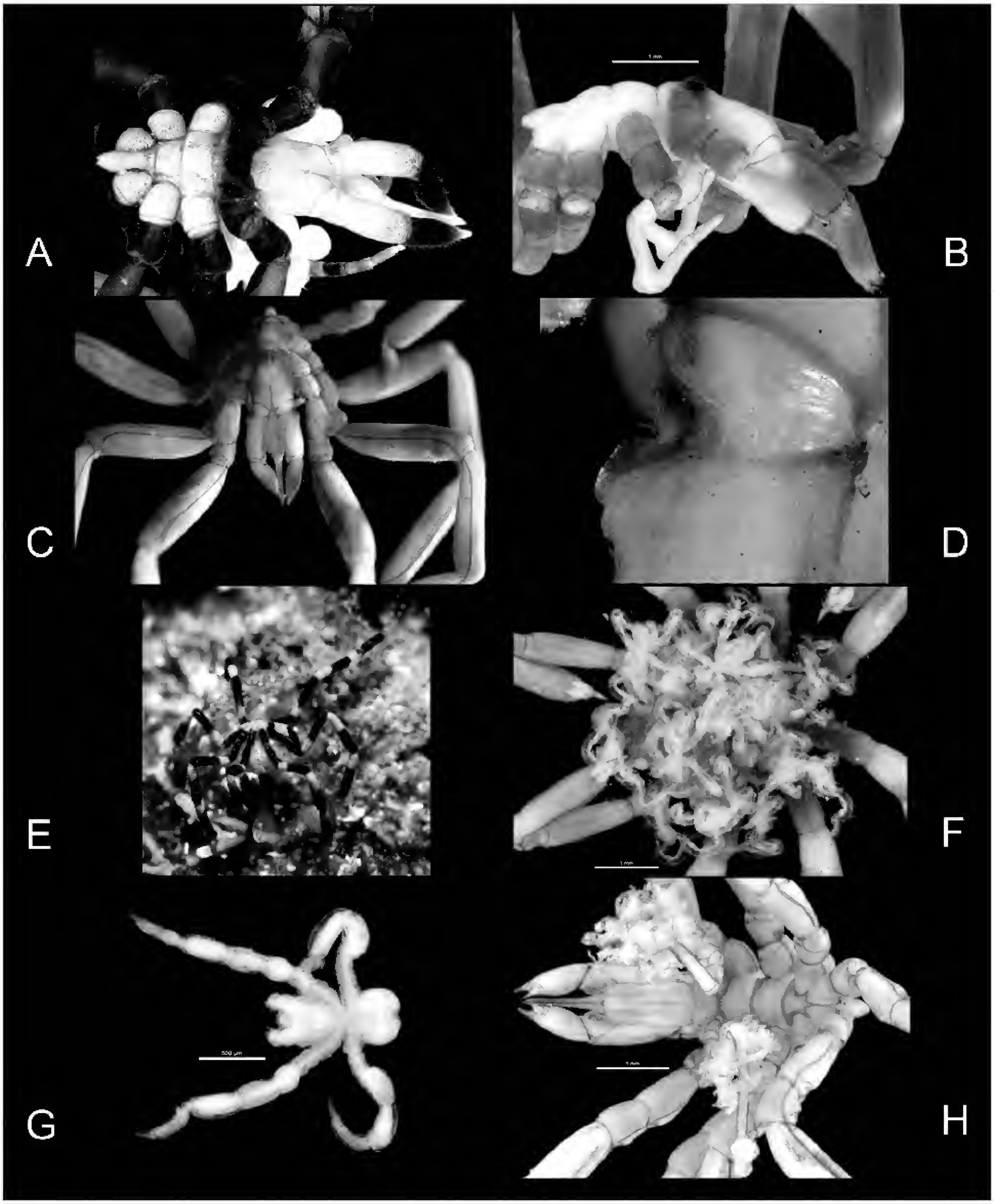

Figure 3. *Stylopallene tubirostris*, A, B, male, dorsal and lateral views of trunk; C, female, anterior view of cephalon; D, scape process; E, live specimen; F, juveniles on male; G, juvenile; H, exuviae attached to male oviger.

region, not reaching beyond distal margin of fourth lateral processes. Palps absent. Chelifores directed forward, apart from spination there is no evidence of sexual dimorphism in the scapes. Chelae directed slightly outwards from midline of scapes, fingers much longer than palm, smooth, carried vertically to each other. Ovigers ten-segmented, both sexes, spines on segments 7-10 compound, few in number, terminal claw absent, male segment 5 longest, with prominent distal apophysis, female segment 4 longest. Legs with numerous spine-tipped tubercles, tibia 2 longest, propodus gently curved without prominent heel. In male, femoral cement glands present. Genital pores on ventrodistal surface of coxa 2 of all legs in both sexes; those of the female larger than the male. Auxiliary claws absent.

Type species. *Stylopallene dorsospinum* Clark, 1963

Etymology. This genus name honors the outstanding contribution by Dr. Roger Bamber to pycnogonid taxonomy and literature. Gender feminine.

Bamberene dorsospina (Clark, 1963)

Zoobank LSID. http://zoobank.org/urn:lsid:zoobank.org:act:FD54384E-DF6A-4763-B1A9-BCC93C4C89F7

Figures 4 A-H

The specific name is here amended to the correct gender ending.

Stylopallene dorsospinum Clark, 1963: 38-40—Staples, 1997: 1055

Material examined. Australia, AM P42848 East of Long Reef, New South Wales 33° 43'S, 151° 46'E, K85-21-08, 174 m, FRV Kapala, 12 Sep 1985, 1 male, 1 female, 2 subadults. AM P43312 off Sydney, NSW, 33° 46'S, 151° 43'E, stn K77-23-01, 176m FRV Kapala, 12 May 1977, 2 males, 2 subadults, 1 juv. NMV J62425 Waterloo Bay, Wilsons Promontory, 10 m, D.A. Staples, 28 Mar 1981, 1 female. NMV J48962 New South Wales, off Nowra, SLOPE 1 (34° 59. 31'S, 151° 05. 56'E), 204m, WHOI epibenthic sled, substrate coarse shell, coll. G.C.B. Poore *et al*., 14 Jul 1986. 1 subadult.

Distribution. Port Phillip, Victoria to Botany Bay, New South Wales. Depth 1-204 m.

Remarks. Leg span 15-20 mm. Clark's description of *S. dorsospinum* is based on three females, a damaged male and two juveniles trawled off Twofold Bay and Wata Mooli, New South Wales. Examination of additional material held in the Australian museum and Museum Victoria has enabled further observations to be recorded. The ocular tubercle has two dorsal papillae. The proboscis is setose distally, the setae surrounding the jaws being much shorter but denser than the proximal setae so much so that the jaws are obscured when closed (fig. 4F). The jaws appear to be soft and flexing, petal-like when open. The arthrodial membrane at the base of the proboscis is broad enabling the proboscis to move through 45° to a vertical position. The movable finger of the chela has an outward bend in the mid-region which is most evident in ventral view (fig. 4F). Near the tip of the finger is a short lip on the inner margin upon which the tip of the immoveable finger comes into contact when the chela is closed. The lip gives the tip of the finger a slightly thickened, bifurcate appearance. The oviger is ten-segmented and a terminal claw is completely lacking (fig. 4D). In the male specimens examined the surfaces of segments 7-10 are covered in filaments which obscure the number of compound spines present. The terminal 'boss-like structure' noted by Clark on the female oviger is not present but several simple (some tiny) spines originate from the surface, compound spines on segments 7-10 are slender with one or two-pair of lateral teeth. The spine formula is variable between specimens but spines are either absent or few (1-4). Several simple spines are also present. A conical swelling on the outer surface of segment 4 in both sexes is probably the site of a gland opening. In the females examined it varies in size between specimens.

In males, femoral cement glands are represented by two pale swellings on the lateral margin of the posterior surface of all legs. Gland openings are obscure (fig. 4B). Spines broken off the dorsodistal part of the femur and elsewhere leave a hollow in the basal tubercle giving the incorrect impression that these are gland ducts. Females are less spinous than males; the spine-tipped tubercles on the chelifore scape are absent and those on the femur are less abundant.

Should *Bamberene dorsospina* adopt the same (dorsal to ventral) mating position as do species of *Meridionale* (Staples 2014, fig. 4A) and *Stylopallene* (fig. 2E), then the presence of mid-dorsal trunk processes would be an encumbrance to the transfer of eggs. This suggests an alternative mating position for this species and perhaps explains the absence of a proximolateral chelifore scape process. In a group of otherwise smooth species, the presence of dorsal processes may be of evolutionary significance. In the light of this observation the standing of *Austropallene cristata* (Bouvier, 1911) within *Austropallene* may need to be reconsidered.

The host substrate and colour markings of *S. dorsospina* are not recorded and evidence of body markings has not persisted in the specimens examined.

Larval and juvenile forms. The protonymphon is attached to the male oviger by a single thread extending from one chelifore. A gland duct is not evident. The proboscis is not completely developed in the early stages. At the stage where the third pair of legs is present but still incompletely developed, the distal tubiform part of the juvenile proboscis is absent. At this stage the mouth is wide and open. The juvenile chela is well-developed, fingers strongly bowed and gaping.

Acknowledgments

I am indebted Philip Bock for identification of bryozoans and to Stephen Keable of the Australian Museum for facilitating specimen loans. To Robert (Bob) Burn I express my gratitude for his helpful advice in addressing nomenclature issues. I am grateful to my son Aaron Staples for the presentation of the images and to my colleagues Melanie Mackenzie and Joanne Taylor for their ongoing assistance. To the reviewers of my manuscript, I express my appreciation for their constructive assessments.

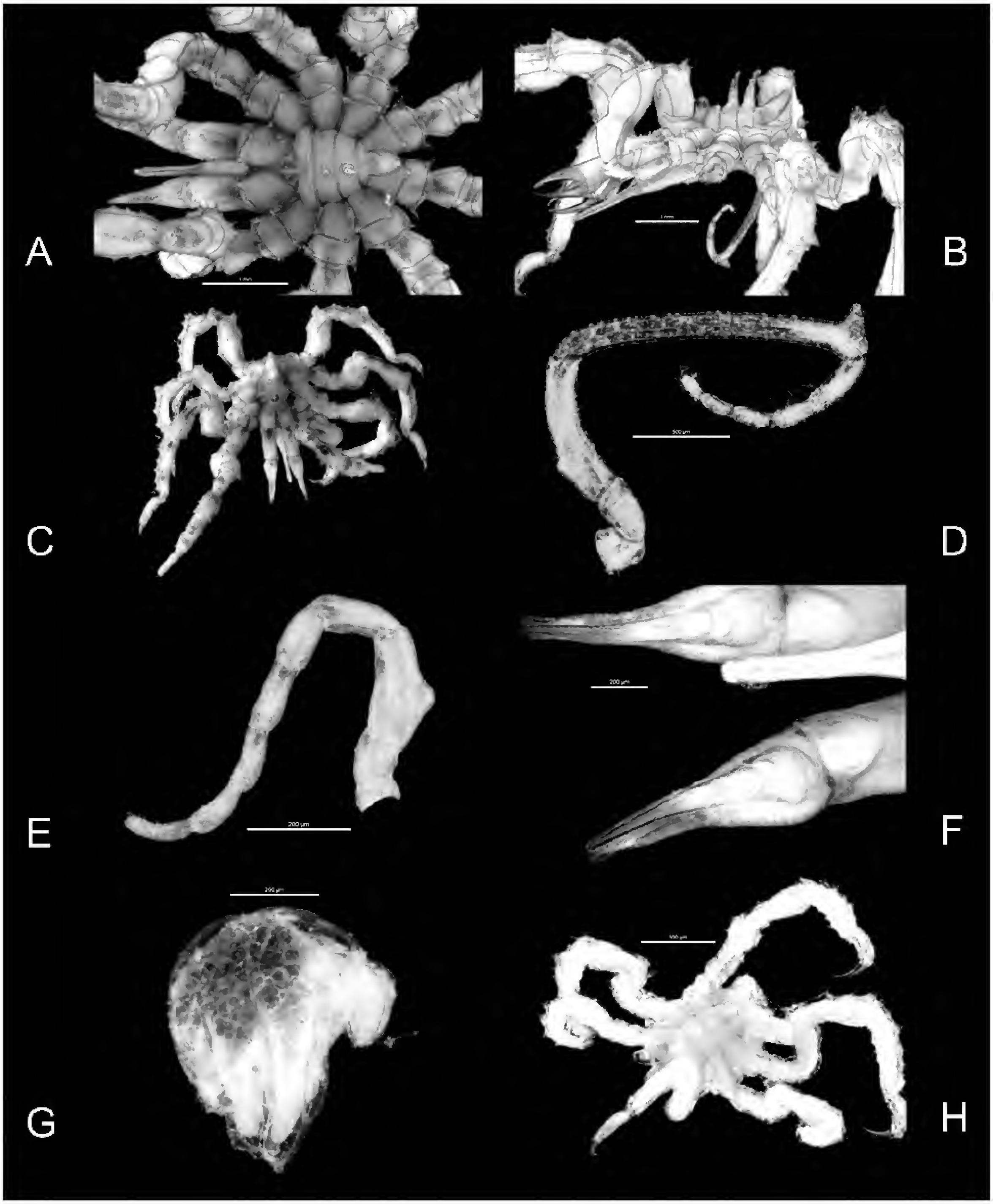

Figure 4. *Bamberene dorsospina*, AM P42848 male, A, B, dorsal and ventral views of trunk; C, anterior view of cephalon: D, male, oviger; E, female oviger; F, NMV J62425, proboscis tip and chelae; G, AM P43312 larva removed from male; H, juvenile removed from male.

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A new species of *Sigsbeia* and additional records of ophiuroids from the Great Australian Bight

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Abstract O'Hara, T.D. and Harding, C. 2014. A new species of *Sigsbeia* and additional records of ophiuroids from the Great Australian Bight. *Memoirs of Museum Victoria* 72: 131-140.

A new species of *Sigsbeia* (Hemieuryalidae: Ophiuroidea) is described from south-western Australia. Previously, all species of Hemieuryalidae *sensu stricto* have been found in the tropical western Atlantic and eastern Pacific Oceans. Consequently, all currently recognised families of Ophiuroidea now have been collected from the Australian and New Zealand region. Additional new ophiuroid records from the Great Australian Bight include *Astrotoma manilense*, *Ophiothrix albostriata*, previously known only from the holotype, and *Ophiomusium scalare*. New Zealand records formerly called *Astrotoma drachi* are referred to *A. manilense*. The available name *Ophiomusium aporum* is synonymised with *O. scalare* rather than *O. incertum* or *O. australe* where it has previously been placed.

Keywords Ophiuroidea, Australia, marine, continental slope, Hemieuryalidae, *Astrotoma*, *Ophiothrix*, *Ophiomusium*

Introduction

As part of a multi-institutional project to survey marine biodiversity on the continental slope of the Great Australian Bight (GAB, for more details see Acknowledgements), one of us (TOH) was commissioned to identify ophiuroids in the South Australian Museum collected from the outer shelf and slope of this region. This report is some taxonomic changes arising from this research, including the description of a new species, one species not seen since the holotype, and alterations to two existing synonymies.

The ophiuroid fauna of the GAB is not well known. Tall cliffs surround much of the coastline preventing ready access to shallow water. Moreover, there have been few targeted expeditions to survey the seafloor biodiversity of either the continental shelf, slope or abyss. The USSR Dmitry Mendeleev Cruise 16 sampled the Bight in February 1976 with the resulting material being deposited in various museums, including Museum Victoria, the Australian Museum, Te Papa in New Zealand, and the Russian Academy of Sciences Institute of Oceanology in Moscow (Baker 1979; Litvinova 2010; O'Hara unpublished). There have been three important expeditions on Australia's research vessel *Franklin* (FR0594, FR0694 and FR0795), the first being a biodiversity study of eastern South-Australia (the second SLOPE survey, lead by Museum Victoria), and the second two examining the formation of bicarbonate sediments (James & Bone 2011). There have been two expeditions on Australia's *RV Southern Surveyor* (SS01/00 and SS03/2008) which sampled a few stations in the GAB in order to characterise the benthos and understand ecosystem function. Most of museum collections from the region have been collected as incidental coastal collections, dredged by the naturalist Sir Joseph Verco between 1890 and 1912 (Verco, 1935) and reported by H.L. Clark (1928), or as bycatch on fishing vessels in the 1980s (O'Hara unpublished data).

Montage photos were taken with a Leica 205C DFC microscope mounted camera and Zerene Stacker software. Abbreviations include: SAM (South Australian Museum, Adelaide), AM (Australian Museum, Sydney), MV (Museum Victoria, Melbourne), MCZ (Museum of Comparative Zoology, Harvard), NIWA (National Institute of Water and Atmospheric Research, Wellington), TMAG (Tasmanian Museum and Art Gallery, Hobart), d.d. (disc diameter).

Systematic Account

Family **Hemieuryalidae**

Sigsbeia oloughlini sp. nov.

Fig. 1 and 2.

Zoobank LSID. http://zoobank.org:act:AE0247F3-DAE5-4F5E-B966-431AD6668EA9

Material examined. -- **Australia**. FR0795: stn 111, SW of Esperance, 34° 23'S, 120° 39'E, 95 m, 1995, holotype: 1 (SAM K4005).

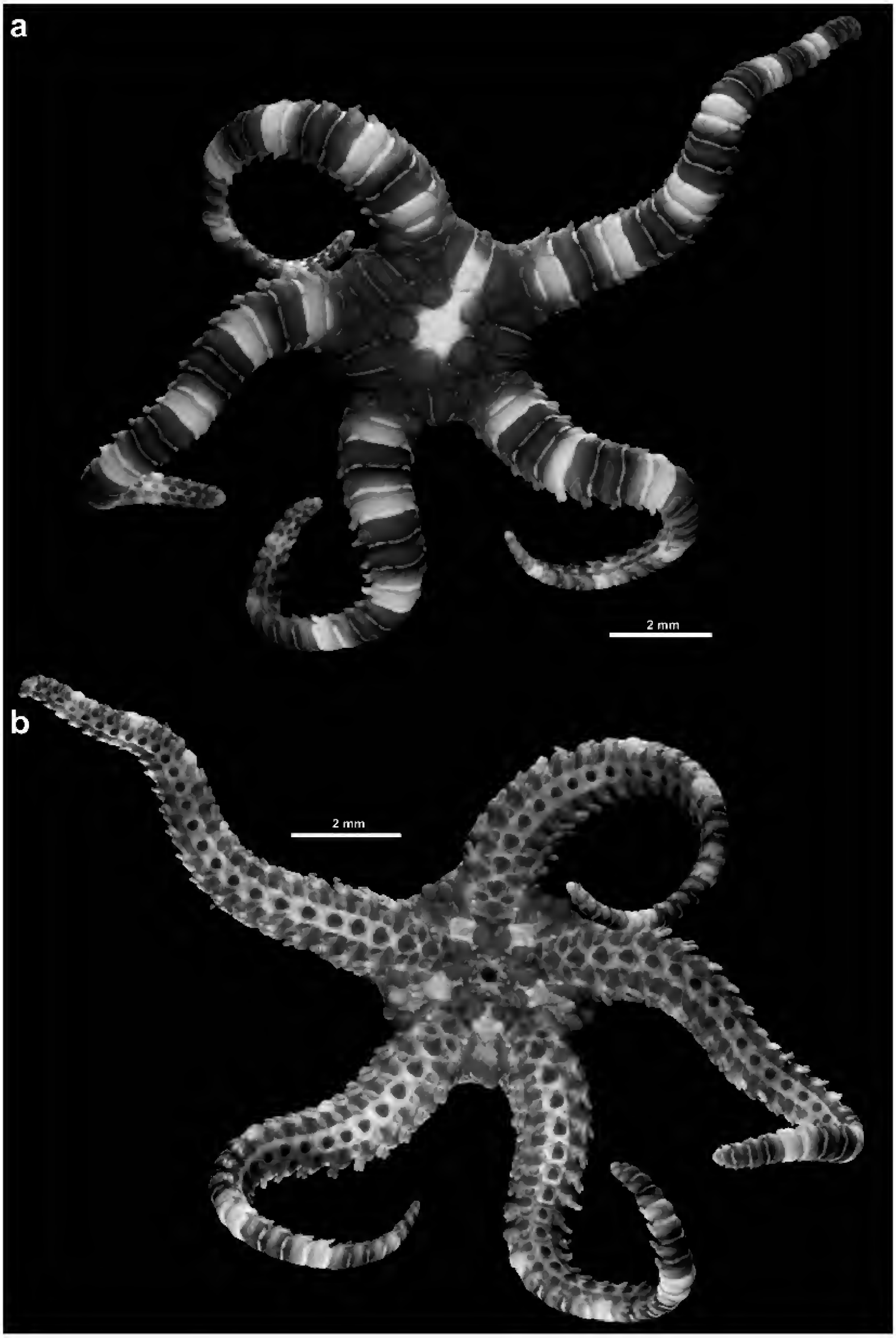

Figure 1. *Sigsbeia oloughlini* sp. nov., holotype SAM K4005, A, dorsal view; B, ventral view.

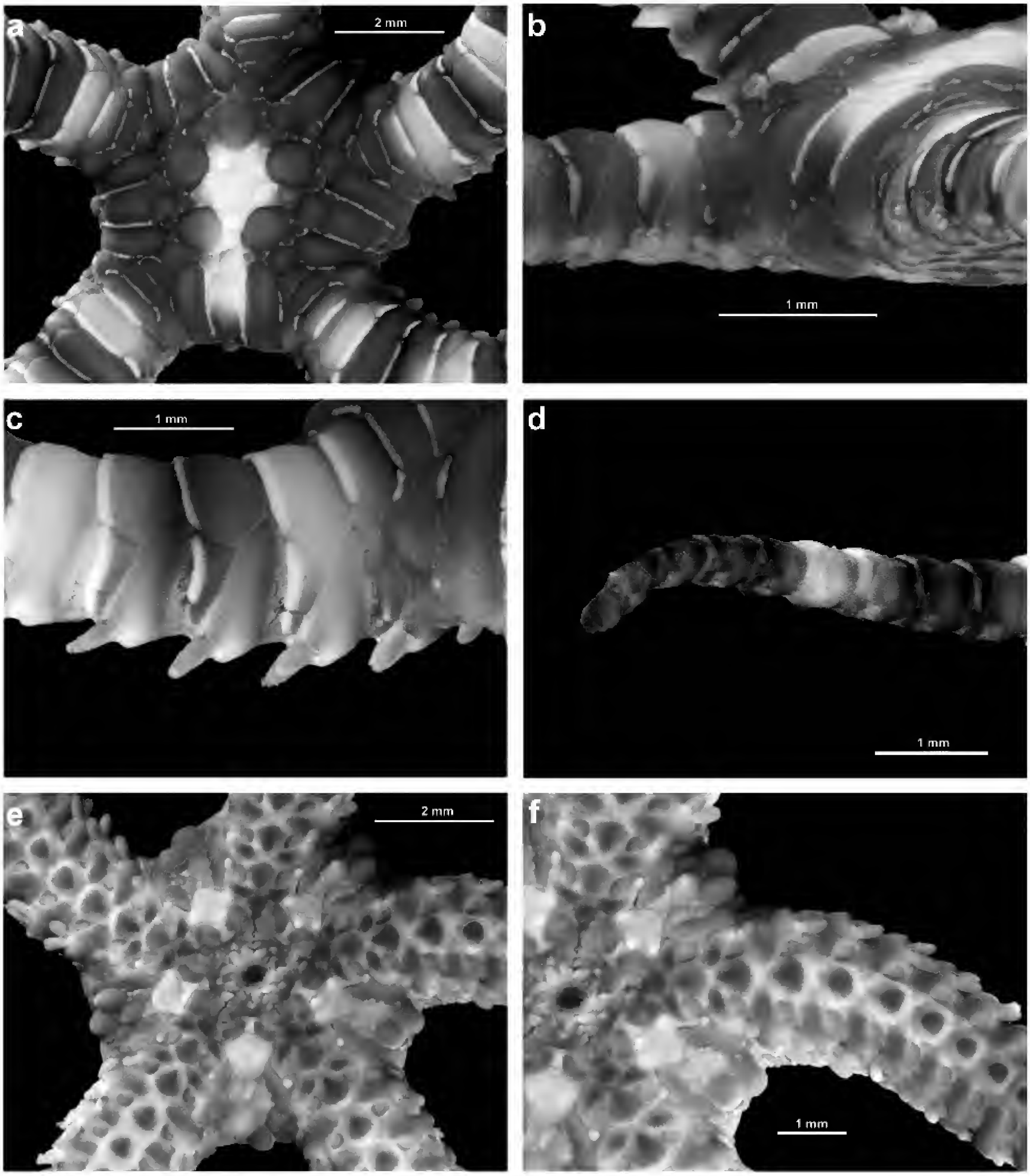

Figure 2. *Sigsbeia oloughlini* sp. nov., holotype SAM K4005, A, dorsal disc details; B, lateral view of disc and arm base; C, lateral view of arm showing supplementary dorsal arm plates; D, arm tip; E, ventral view of disc; F, ventral view of disc and base of arm.

Description. Disc 4.8 mm d.d., arms five, approximately 14 mm long. Disc round to pentagonal, covered in flat polygonal to rounded plates. Primary disc plates are distinct, separated by a series of small interradial plates. A 2nd circle of larger radial and interradial plates occurs near the proximal end of the radial shields, separated by small intercalary platelets. A long narrow plate is present at the interradial margin, 2 times as long as wide, separated from the parallel radial shields by a single series of small platelets. The radial shields are long narrow plates, 3.5-4 times as long as wide, that extend from near the arm base, around the arm, to the latero-ventral edge of the disc. They converge proximally, but do not touch, separated by the secondary radial plate. There are 1-3 tumid quadrangular to triangular plates on the lower side of each arm base, adjacent to the radial shield, which are potentially homologous to the series of plates distal to the radial shields in *Ophiolepis* and *Ophiozonella*.

The ventral interradial disc is completely covered in plates, including short wide plates at the proximal margin, probably rudimentary genital scales. The central area is dominated by 2-3 tumid to protuberant plates, surrounded by 1-2 series of small intercalary platelets. The genital slits are small, and extend from the oral shield for the length of the 1st lateral arm plate.

The jaws are wider than long, with 4 oral papillae on each side that almost completely cover the jaw slit; the inner ones are block-like (almost resembling the infradental papillae on amphiurids), the 2nd and 3rd are smaller, trapezoid, slightly longer than wide, the distal ones are enlarged, 1-5-2 times as wide as long, with an angle proximally and a sloping distal edge. There is also a tiny recurved scale wrapped around the 2nd oral tentacle pore near the apex of the slit. The oral shields are roughly pentagonal, with rounded angles and concave proximo-lateral margins, as wide as long. The madreporite is distinct and enlarged. The adoral shields are sausage-shaped, 2 times as wide as long, separated proximally by a triangular intercalary plate.

The 1st dorsal arm plates are triangular, 2 times as wide as long, and are placed where the arm is inserted into the disc, adjacent to the secondary radial plate and proximal ends of the radial shields. Subsequent plates are oblong to hexagonal, becoming progressively larger and longer from the 2nd to 4th plate, 2-4 times as wide as long with straight proximal and distal margins and a convex to angular lateral margins, fully contiguous until about the 12th plate, after which they become pronounced proximally, as wide as long, and narrowly separate. There are 1-3 accessory dorsal arm plates extending from the distolateral edge of each dorsal arm plate. The largest accessory plate is triangular and contiguous with the main dorsal arm plate. There is often a smaller triangular plate extending from the ventral corner of the larger plate to near the upper arm spine. A tiny intercalary plate is sometimes present at the distal junction of the main dorsal and largest accessory arm plate. The first 2 arm segments have only a single accessory plate angled distally with respect to the dorsal arm plate.

The lateral arm plate extends around the arm from the dorsal to ventral arm plate, having a swollen ventro-distal flange which usually bears 2 small cylindrical arm spines, the upper is 2 times as tall as wide with a blunt rounded apex, the lower is slightly longer or subequal, to 2/3rds the length of the arm segment. There is one, almost granule-like, spine on the first segment and up to 3 cylindrical spines on some segments near the arm tip.

The 1st ventral arm plate is rounded-triangular, the proximal angle forms the apex of the jaw slit, the proximolateral sides are contiguous with the adoral plates and the lateral end of the distal margin with the first lateral arm plates, the centre of the distal margin is contiguous with the 2nd ventral arm plate. The 2nd plate is bell-shaped to pentagonal, with a curved to angular proximal margin, sides recurved around the tentacle pore, and a convex distal margin. From the 3rd plate, the plates are sunken around the margin and covered in thick epithelium or connective tissue, the raised central portion of the plate is pentagonal to ovoid, the 3rd and 4th slightly wider than long, and thereafter as wide as long. The tentacle pores are oval, the base as long as the raised section of the ventral arm plate, but becoming progressively shorter. A thin sunken oval tentacle scale almost completely covers the pore.

The colour (in ethanol) is brown and white. The dorsal disc is mostly brown, except for a splash of white from the centre to one interradial margin and series of small white intercalary plates around the radial shields. Arms are banded, with 1-2 pale and 2-3 darker segments; in addition, there is a strong narrow transverse white band along the distal edge of each dorsal arm plate and adjacent accessory plates. The oral shields (often with whiter proximal apices), ventral disc plates adjacent to the oral shields and the intercalary plate separating the adoral shields are also pale. The distal ventral disc plates, raised section of the ventral arm plates, lateral arm plates, tentacle scales, adoral shields and oral plates are brown.

Distribution. Southwestern Western Australia, 95 m

Remarks. Despite being known from only one specimen, which precludes dissection, this species has characteristic features that warrant its description. We place it in the genus *Sigsbeia* in the family Hemieuryalidae on the basis of the coiled arms, adapted for an epizoic habit, the integration of the arms into the disc, the narrow radial shields that extend around the lateral disc margin almost to the ventral surface, the presence of accessory plates at the distal lateral corners of the dorsal arm plates, the single tentacle scale and the second oral tentacle pore hidden within the jaw slit.

Matsumoto (1915) recognised two subfamilies within the Hemieuryalidae, the Hemieuryalinae with supplementary or subdivided dorsal arm plates and the Ophiochondrinae with entire plates. Martynov (2010) reviewed several genera within the Ophiochondrinae and on the basis of their arm spine articulation morphology regarded them as belonging to the Ophiacanthidae. He thus restricted the Hemieuryalidae to those genera formerly in the Hemieuryalinae, explicitly *Hemieuryale* von Martens, 1867 and *Sigsbeia* Lyman, 1878b. To these we can add the similar genera *Quironia* A.H. Clark, 1934, *Ophioplus* Verrill, 1899, and *Ophioholcus* H.L. Clark, 1915. Two additional genera remain problematic and require further study. *Ophioleila* A.H. Clark, 1949 is superficially similar to *Ophioplinthaca*, an ophiacanthid, and *Amphigyptis* Nielsen, 1932 was provisionally referred to the synonymy of the amphiurid *Axiognathus* (=*Amphipholis*) by Thomas (1966).

The other genera of hemieuryalids are separated from *Sigsbeia* as follows (Fell 1960). *Hemieuryale* has fragmented dorsal arm plates, *Ophioholcus* has 6 arms and contiguous radial shields, *Quironia* also has 6 arms and a single genital slit in each interradius that continues around the distal edge of the oral shield, and *Ophioplus* has a few accessory plates spaced along the distal edge of the dorsal arm plates. All four of these genera are monospecific, with their species restricted to the Caribbean/Western Atlantic continental shelf and upper slope.

The four previously known species of *Sigsbeia* differ from *S. oloughlini* most notably in the morphology of the disc plates, dorsal arm plates, arm spines and colour pattern. The type species, *S. murrhina* Lyman, 1878b (holotype: 12 mm d.d.) and *S. conifera* Koehler, 1914 (5 mm d.d.), both from the Caribbean, have granulated disc plates, a single rectangular to ovoid accessory dorsal arm plate, and two rounded, slightly flattened, arm spines. Furthermore, on *S. conifera* some of the larger dorsal disc plates are tumid and the dorsal plates non-contiguous after the basal few. *Sigsbeia lineata* Lütken & Mortensen, 1899 from the Galapagos and Cocos Islands has smooth disc plates without granules and the inner end of the ventral arm plates sunken like on *S. oloughlini*; but has flat widened arm spines, a trapezoid accessory arm plate, and two thin longitudinal stripes running from the disc down each side of the dorsal arm surface. Finally, *Sigsbeia laevis* Ziesenhene, 1940 from the Pacific coast of Panama has tumid but ungranulated disc plates, small dorsal arm plates, as long as wide, barely contiguous, and flattened plate-like ovoid arm spines, and a squarish to rounded accessory arm plate. None of these species have the tumid ventral disc plates characteristic of *S. oloughlini*.

Different authors have disagreed about the nature of the accessory dorsal arm plates. While Lyman (1878b), Koehler (1914) and Fell (1960) have treated them as accessory arm plates, Lütken & Mortensen (1899) and Ziesenhenne (1940) considered them as highly modified upper arm spines that overlie the lateral arm plate. While the ontology of these plates cannot be fully addressed from our single specimen, here they do appear to be true plates, lying in a series confluent with the dorsal arm plate and abutting the edge of the previous lateral arm plate. They do not align with the two arm spines which emerge from a distal flange of the lateral arm plate. Moreover, where these accessory plates are missing, the underlying areas appear to be at least partially decalcified, suggesting that they are dorsal arm plates. Under this interpretation, these plates and the arm spines have converged in morphology in *S. laevis* and *S. lineata*, possibly functioning as a frictional aide to climbing.

The position of the accessory dorsal arm plates in *S. oloughlini* recalls *Ophiolepis species* such as *O. elegans* Lütken, 1859 or *O. superba* H.L. Clark, 1915b. In fact, the overall morphology is quite similar to *Ophiolepis*, including the integration of the arms into the disc, the form of the oral frame, and the disc plating. In particular, the row of disc plates that are placed distal to the radial shields in *Ophiolepis* and related genera are also apparent in *Sigsbeia* - the middle plate placed between the proximal ends of the radial shields and the lateral ones positioned at the base of the arm between the radial shields and third dorsal arm plate. *Ophiolepis* can be distinguished by its smaller radial shields, which are largely restricted to the dorsal surface and the long genital slits bordered by elongated genital scales.

This is the first record of a hemieuryalid species outside the equatorial western Atlantic and eastern Pacific. Now all recognised families of ophiuroids have been recorded from the Australian/New Zealand region. The new record from the outer continental shelf off SW Australia may indicate a lack of sampling at these depths from this region. Three of the other four *Sigsbeia* have been recorded living on stylasterids. The catch description for this sample did not record stylasterids explicitly but did record abundant octocorals, ascidians, sponges, and bryozoans.

Etymology. Named after Mark O'Loughlin, teacher, mentor and friend (of TOH) for over 35 years.

Family **Gorgonocephalidae**

Astrotoma manilense Döderlein, 1927

Astrotoma manilense Döderlein, 1927: 19-21, pl. 1(1-1b).

Astrotoma drachi.--McKnight, 2000: 68, fig. 33, pl. 32.--Okanishi & Fujita, 2013: 569 [Non *Astrotoma drachi* Guille A, 1979].

Material examined. **Great Australian Bight**. 110 nm due W of Whidbey Point, 34° 65'S, 132° 51'E, 880-940 m, 1989: 2 (SAM K2734). -- 165 nm SW of Eucla, 33° 23'S, 126° 26.3'E, 391-398 m, 1988: 1 (SAM K3105). -- 75 nm ESE of Cape Arid, 34° 15'S, 124° 42'E, 920-1120 m, 1989: 1 (SAM K2732). -- 105 nm SSE of Eucla, 33° 35'S, 129° 4'E, 860-931 m, 1989: 4 (SAM K2731). -- Adelaide Pearl: stn 15, 125 nm E of Cape Arid, 34° 3'S, 125° 31'E, 1011-1020 m, 1988: 1 (SAM K2763). -- Adelaide Pearl: stn 28, 125 nm S of Eucla, 33° 45'S, 129° 17'E, 999-1110 m, 1988: 3 (SAM K2762); 1 (SAM K2726).-- 80 nm SW of Pearson Is, 35° 4'S, 133° 35'E, 900-960 m, 1989: 1 (SAM K3106). -- Margaret Phillipa 6: stn 4, South of Ceduna, 33° 48'S, 130° 33'E to 33° 42'S, 130° 31'E, 1040 m, 1984: 3 (TMAG H1985).

New South Wales. NZOI: stn U223, east of Newcastle, New South Wales, Australia, 32° 58.8'S, 152° 41.598'E, 1150 m, 1982: 1 (NIWA 49781). -- K88-22: stn 01, east of Ulladulla, 35° 27'S, 150° 54'E, 1060-1123 m, 1988: 1 (AM J22108).

New Zealand. TAN0604: stn 133, Shipley Seamount, 41° 48.072'S, 179° 29.61'W to 41° 48.03'S, 179° 30.198'W, 1240-1275 m, 2006: 1 (NIWA 42265). -- TAN0705: stn 211, 9D19, 42° 39.28'S, 177° 12.792'W to 42° 38.88'S, 177° 12.462'W, 1377-1402 m, 2007, identified by Okanishi & Fujita (2013) as *Astrotoma drachi*: 1 (NIWA 30980). -- NZOI: stn I666, 47° 47.502'S, 178° 59.502'W, 1165 m, 1979, identified by McKnight (2000) as *Astrotoma drachi*: 1 (NIWA 48404); 1 (NIWA 48405). -- TRIP1650: stn 23, 46° 45'S, 170° 3'E, 1036-1312 m, 2002: 1 (NIWA 49785).-- TRIP2124: stn 21, 49° 17'S, 176° 18'E, 1192-1300 m, 2006: 1 (NIWA 75841).

Distribution. Philippines (721 m), Japan (660-710 m), Great Australian Bight (391-1120 m), Eastern Australia (1060-1150 m), SE New Zealand (1036-1402 m).

Remarks. There is a large *Astrotoma* species present on the continental slope of southern Australia and New Zealand in 400-1400 m. Specimens collected to date form three populations, in the Great Australian Bight, off New South Wales and off south-east New Zealand, including the Campbell Plateau and the Chatham Rise. The latter population was first reported by McKnight (2000) who referred one lot (NZOI I666) to the species *A. drachi* Guille, 1979 without comment. This is one of three similar species of *Astrotoma* reported from a few specimens from the Philippines and Japan. The differences between these species are minor, slight modifications to the shape and density of the disc tubercles on the disc and the number of arm spines, and may be related to size, with the holotype of *A. manilense* measuring 31 mm d.d., *A. drachi* is 15 mm d.d., and *A. deficiens* Koehler, 1922 is 21 mm d.d..

Examination of a series of specimens from the Great Australian Bight indicates that there is some variation with growth. Smaller specimens (e.g. 2 specimens in SAM K2762; 10-12 mm d.d.) appear like *A. drachi* with 2 (rarely 3) arm spines, sparse disc tubercles, and granular suboral papillae. Larger specimens are like *A. manilense* (e.g., SAM K3106, K3105; 25 & 34 mm d.d.) with a variable (medium to dense) coating of stout hemispherical to cylindrical disc tubercles on the radial shields and interradial margin, 3 (rarely 4) arm spines and spiniform suboral papillae. *Astrotoma deficiens* may differ in predominantly having conical pointed disc tubercles.

Without examining a range of specimens from the Philippines, we are hesitant to formally synonymise any of these species. However, there is no evidence of multiple species in the Australian and New Zealand region and we refer all specimens to the species *A. manilense*, as this name has date priority and represents the adult form. We note that no specimens of *Astrotoma* have been found in the tropical southern hemisphere, including the densely sampled New Caledonian region. Thus, as defined here, *A. manilense* has a disjunct distribution, with at least four isolated populations. Molecular data is required to further investigate species boundaries in this genus. The species is adequately figured my McKnight (2000).

The only other species of *Astrotoma* is the type *A. agassizii* Lyman, 1875 from circum-Antarctica and southern South America. It differs from the other species in having a covering of fine granules on the disc. *Astrotoma agassizii* has been found to both brood young and have a pelagic larva (Heimeier et al. 2010) and Hunter & Halanych (2008) also found several separate genetic lineages that may indicate cryptic speciation.

Family **Ophiotrichidae**

Ophiothrix* (*Placophiothrix*) *albostriata H.L. Clark, 1928

Fig. 3

Ophiothrix albostriata Clark, H.L., 1928: 429-430, fig. 127.

Placophiothrix albostriata.--Clark, H.L., 1946: 227.

Ophiothrix (*Placophiothrix*) *albostriata*.--Clark, A.M., 1967: 648.--Baker & Devaney, 1981: 167, fig. 49-54.--Rowe & Gates, 1995: 427.

Material examined. -- Great Australian Bight, holotype: 1 (SAM K215). -- Great Australian Bight, 75 nm SSW of Pearson Is, 35° 8'S, 133° 47'E, 920-1040 m, 1989: 2 (SAM K2748).

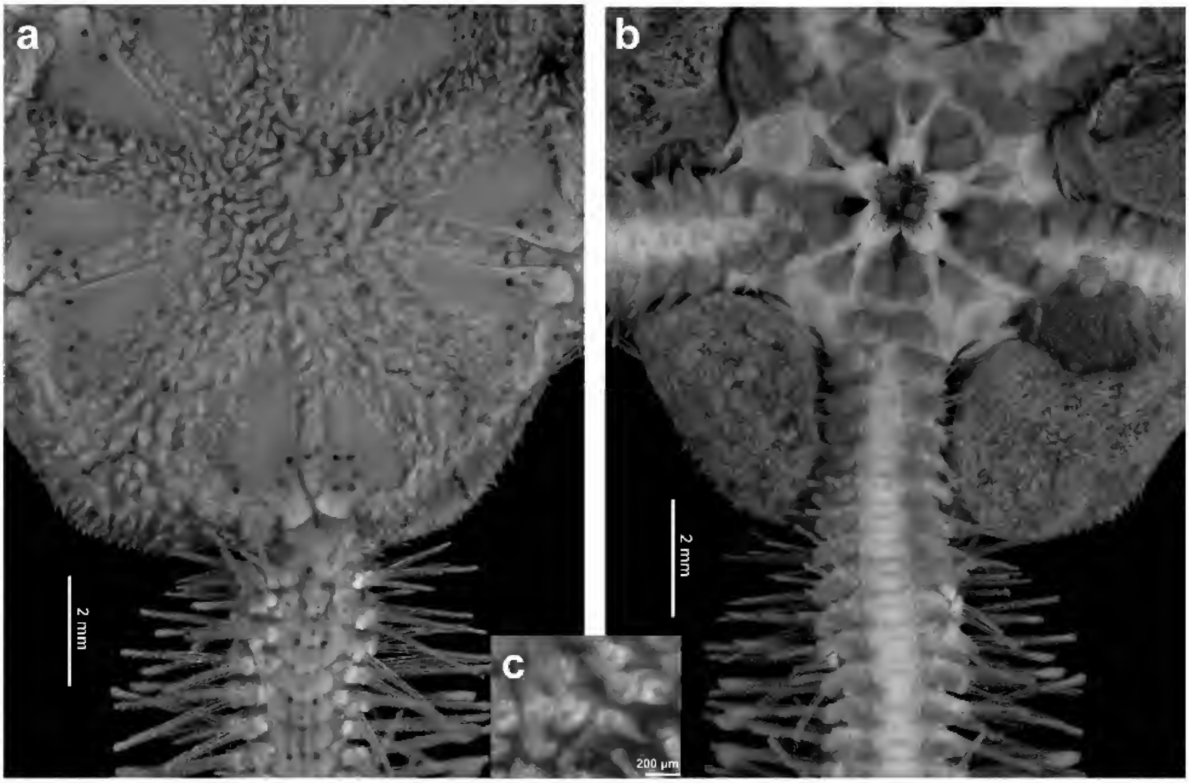

Figure 3. *Ophiothrix albostriata* H.L. Clark, 1928, SAM K2748, A, dorsal view of disc and arm base, B, ventral view of disc and arm base; C, details of disc spinelets visible through epithelium.

Distribution. Great Australian Bight, ?200-1040 m.

Remarks. This is the first record of this species since the 10 mm d.d. holotype was described by H.L. Clark in 1928. Baker & Devaney (1981) figured the dorsal disc and arms of the holotype. Key diagnostic characters include the large (2/5 d.d.) naked radial shields; the tall (3-4x longer than wide) cylindrical disc stumps with a crown of small thorns; the wide (2x as wide as long) dorsal arm plates, with a centrally produced distal margin, and two longitudinal lines (after the 20th segment); up to 9 arm spines, the longest (2-3rd from the top) measuring 2x the width of the dorsal arm plate, slightly expanded at the tip, with thorns largely restricted to the apical half of the spine; oral shield diamond-shaped, twice as wide as long; ventral arm plates rectangular, 1.5x as wide as long, with a straight distal edge, and a minute tentacle scale that becomes hook-shaped distally with 2-3 accessory points.

The two new specimens are considerably larger than the type, 16 and 17 mm d.d., but share many of the features. Differences include the elongated thorns on the disc spines, which can measure ½ the height of the spine, the presence of a row of minute spines along the abradial edge of the radial shield, and the distal edge of the dorsal arm plates with is convex rather than medially produced. The largest specimen (Fig. 3a) has three longitudinal broken lines along the arm, occasionally darkened into discrete spots, which can also occur at the distal end of the radial shields.

These specimens were collected from 920-1040 m, which is exceptionally deep for an ophiotrichid. The collection details on the type specimen only list the locality (Great Australian Bight) and not the depth, latitude/longitude or date. Like many other specimens described by H.L. Clark in 1928, they were presumably collected by the malacologist Joseph Verco, who is known to have participated in an expedition by the Australian fishery research vessel 'Endeavour' to the Great Australian Bight in March 1909 (Verco 1935). They trawled predominately along the "one hundred fathom line" in approximately 125-220 m of water in an area 30-120 nautical miles (55-222 km) west of Eucla. Possibly this species is restricted to the upper continental slope (200-1040 m).

Family **Ophiolepididae**

Ophiomusium scalare Lyman, 1878

Fig. 4

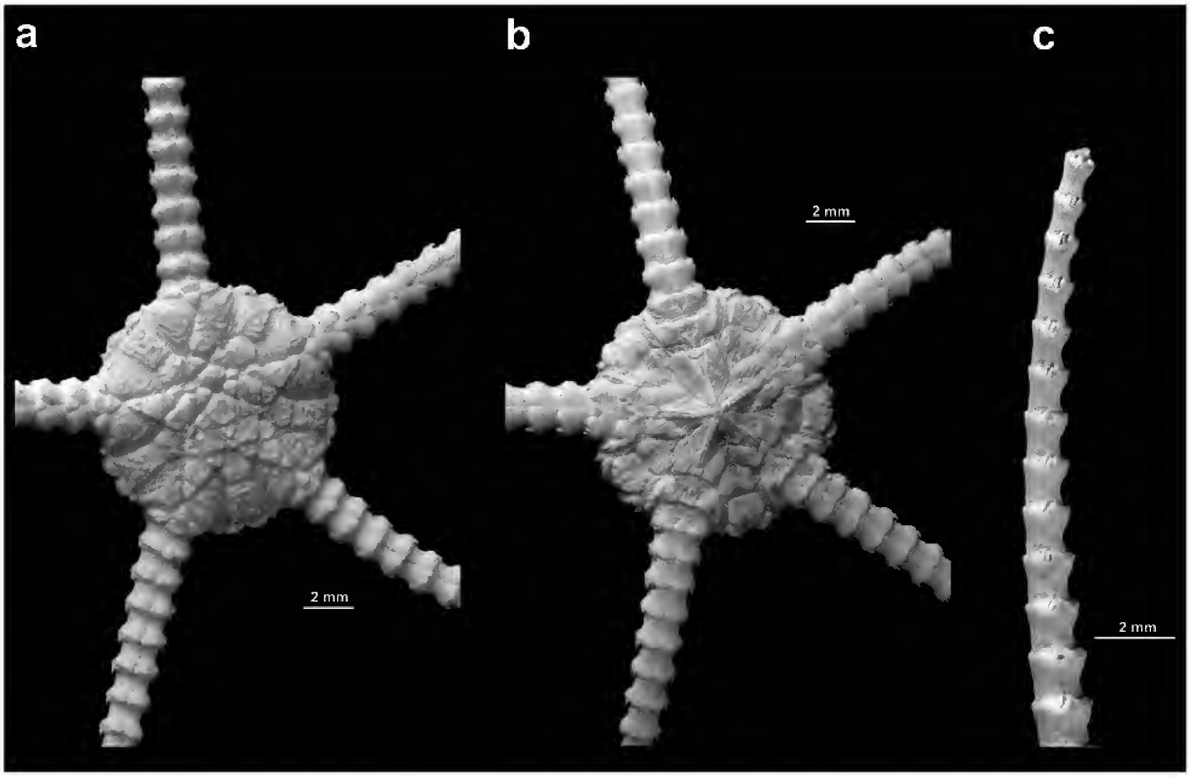

Figure 4. *Ophiomusium scalare* Lyman, 1878, MV F214065, A, dorsal view of disc and arm base, B, ventral view of disc and arm base; C, lateral view of arm segments from mid arm showing the three short arm spines clustered together (broken off from some segments), the middle arm spine is microscopically hooked distally.

Ophiomusium scalare Lyman, 1878a: 117-118, pl. 1(1-3).--Lyman, 1882: 95-96, pl. 1(4-6).--Koehler, 1897: 308-312, pl. 6(24-25).--Koehler, 1899: 26-28, pl. 2(12-13), 3(21).--Koehler, 1904: 65.--Clark, H.L., 1915a: 334.--Matsumoto, 1917: 285-268, fig. 77.--Koehler, 1922: 417, pl. 89(7), 90(1-2).--Koehler, 1930: 242-243.--McKnight, 1975: 64-65.--Irimura, 1981: 40-41.--Guille, 1981: 454, pl. 9(56-57).--Vadon & Guille, 1984: 584.--Rowe, 1989: 287.--Imaoka et al., 1990: 93, fig. 51.--McKnight, 1993: 176, 189.--Liao & Clark, A.M. 1995: 296-297, fig. 167.--Rowe & Gates, 1995: 435.--Stöhr, 2011: 45-46, fig. 21g-I.

Ophiomusium aporum Clark, H.L., 1928: 447-449, fig. 134.--Clark, H.L., 1946: 275 [new synonymy].

Non *Ophiomusium aporum*.--Madsen, 1967: 143, fig. 8 [= *Ophiomusium incertum* Koehler R, 1930; according to Baker, 1979].

Material examined. -- 'Spencer and St Vincent Gulfs', holotype of *O. aporum*: 1 (SAM K255). -- 100 nm SSE of Cape du Couedic, 900-1000 m, 1988: 1 (SAM K3990). -- SS03/2008: stn 47, Great Australian Bight, 35° 12.564'S, 134° 27.012'E, 456 m, 2008 to 2008: 1 (MV F159801). -- SS03/2008: stn 69, 35° 8.436'S, 134° 16.482'E, 450 m, 2008 to 2008: 15 (MV F159741). -- SS03/2008: stn 126, 35° 13.77'S, 134° 30.798'E to 35° 14.268'S, 134° 30.78'E, 300-400 m, 2008 to 2008: 4 (MV F159752). -- SLOPE: stn 203, Off Murray River mouth Encounter Bay, 37° 1.42'S, 137° 44.19'E to 37° 1.13'S, 137° 44.18'E, 403 m, 1994 to 1994: 18 (MV F89438). -- FR0694: stn 22, 58 nm SW Coffin Bay, 35° 27'S, 134° 48.6'E, 300-400 m, 1994: 10 (SAM K2770). -- SS10/2005: stn 80, Jurien Bay, 29° 50.514'S, 114° 21.72'E to 29° 51.012'S, 114° 22.02'E, 408-427 m, 2005 to 2005: 7 (MV F112020). -- SS10/2005: stn 34, Bald Island, 35° 12.81'S, 118° 39.06'E to 35° 12.24'S, 118° 40.14'E, 431-408 m, 2005 to 2005: 300 (MV F111164).

Distribution. India, Indonesia, western and south-western Australia, Philippines, Japan, SW Pacific from Papua New Guinea to the northern Louisville Ridge. Depth range 124-1100 m

Remarks. H.L. Clark (1928) described two specimens of *Ophiomusium* from South Australia as a new species *O. aporum*. However, in 1946 he subsequently synonymised his species with *O. incertum* Koehler, 1930, the existence of which he had been unaware in 1928. Baker (1979) re-examined both specimens and referred the holotype (SAM K481) to *O. australis* H.L. Clark, 1928, on the basis that tentacle pores are present on the first two arm segments, but leaving the smaller 3.3 mm d.d. paratype (MCZ 4712) as *O. incertum*.

However, after examination of hundreds of *Ophiomusium* specimens from southern Australia, we consider that there are three species characterised by having two-tumid plates along each disc margin. These are 1) *O. australe* with smooth disc plates, two arm spines (see O'Hara 1990), two ventral arm plates and pore pairs (see Baker & Devaney 1981 fig. 25-28), 2) *O. incertum* with granulated disc plates, 3-5 arm spines, no obvious pore pairs (except in small juveniles, see O'Hara 1990), and no ventral arm plates (see Madsen 1967 fig. 8), and 3) *O. scalare* with disc covered in wrinkled skin, 3 arm spines, and two ventral arm plates and pore pairs.

We judge that the holotype of *Ophiomusium aporum* is closer to *O. scalare* than *O. incertum*, as it has wrinkled skin on the disc, two (although frequently indistinct) pore pairs, and 3 arm spines. However, *O. scalare* is morphologically variable (particularly the appearance of the dorsal disc) across its large range and the form found off SW Australia could easily be a separate cryptic species for which the name *O. aporum* would be available. *Ophiomusium scalare* is known from the Andaman Islands to Tonga, and Japan to the Taupo Seamount in the Tasman Sea. It usually occurs in 100-1500 m. A very similar species, *O. ultima* Hertz, 1927 has been recorded off eastern Africa. We have not had the opportunity to examine the smaller paratype of *O. aporum* in the MCZ which has been described as having no tentacle pores and a granulated disc. Our other records of *O. incertum* are restricted to Tasmania and eastern Bass Strait.

Discussion

The last major study on the ophiuroids of the GAB was by H.L. Clark (1928), where he described or reported species from the South Australian Museum collections, many dredged by the naturalist Joseph Verco. Unfortunately, the location data on many of these specimens were imprecise and assumed to be St Vincent and Spencer Gulfs where Verco did much of his dredging. Verco also dredged along the upper continental slope off Beachport (to 550 m) and Kangaroo Island (to 210 m) (Verco 1935). This is significant as the seafloor depth in the Gulfs is limited to less than 40 m but many of the species reported by Clark have only been subsequently found on the outer continental shelf or more usually the upper continental slope (> 100 m) (O'Hara, unpublished information). These species include *Ophioscolex* cf *glacialis*, *Ophiacantha brachygnatha*, *Amphiophiura collecta* (=*A. urbana*), *Ophiura ooplax*, *Ophiomusium anisacanthum*, *O. simplex* var *australe* (=*O. australe*), and *O. aporum* (=*O. scalare*, see above), and *Ophiozonella elevata* (=*O. bispinosa*). Thus it is likely that the reported localities for all these species (and the type localities of *O. brachygnatha* and the *Ophiomusium* spp) are the upper continental slope of eastern to central South Australia.

The discovery of new ophiuroid species on the continental shelf and upper slope of South Australia indicates that the fauna is still inadequately sampled to be complete. The report of a hemieuryalid species on the Southern Australian coast is remarkable as this family (as now restricted) has previously only been found in the tropical western Atlantic and eastern Pacific. However, this trans-Pacific distribution also occurs in some other relict genera. For example *Ophiopteris* species are only known from New Zealand and California (Devaney 1970). Extant *Ophiocrossota* is only known from southern Australia (*O. multispina*); however, fossils of this easily recognised genus have also been found from the Miocene and Eocene of the western United States (Blake, 1975; Blake & Allison 1970) and the Miocene of Patagonia (Caviglia et al. 2007).

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Value and impacts of collecting vertebrate voucher specimens, with guidelines for ethical collection

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Abstract Clemann, N., Rowe, K.M.C., Rowe, K.C., Raadik, T., Gomon, M., Menkhorst, P., Sumner, J., Bray, D., Norman, M. and Melville, J. 2014. Value and impacts of collecting vertebrate voucher specimens, with guidelines for ethical collection. *Memoirs of Museum Victoria* 72: 141-151.

Museum collections of preserved faunal specimens are immensely valuable resources for understanding the natural world, and such understanding has a crucial role to play during the current biodiversity extinction crisis. Collections of specimens, and the benefits accrued by collections, are not static; new and fresh specimens, or specimens from uncollected localities or of differing demographics, are always needed. Despite this, resistance to collecting specimens is mounting, as is an erroneous belief that modern techniques (such as molecular analyses) and technologies (such as digital cameras and tracking devices) negate the need to collect specimens. Contemporary technology sometimes facilitates a reduction in the number of voucher specimens that need to be collected, but it does not eliminate the need to collect. Concerns about animal rights have and will continue to play a crucial and desirable role in rectifying unnecessarily poor treatment of fauna, but we believe that judicious collection of specimens is at times a higher priority than preserving the life of every possible individual. We argue that museum collections provide essential verifiable evidence of species' occurrence over time and space, and thus permit rigorous taxonomic, biological and ecological investigations. The value of specimen data for these studies today and for the decades and centuries that follow, justifies the judicious collecting of specimens. Using local examples, we demonstrate the benefits provided by specimens, the need for continued collecting in Victoria, and a framework with which to guide the decision-making process for the collection of vertebrate specimens.

Keywords voucher specimen, fauna, museum, Victoria, natural history collections

Introduction

"*At this point I wish to emphasize what I believe will ultimately prove to be the greatest value of our museum. This value will not, however, be realized until the lapse of many years, possibly a century, assuming that our material is safely preserved. And this is that the student of the future will have access to the original record of faunal conditions in California and the west, wherever we now work.*" (Grinnell 1910, p. 166).

Collections of voucher specimens that are catalogued and curated in museums provide a critical foundation for taxonomy, evolutionary biology, biodiversity research, conservation biology, and public health and safety (Suarez and Tsutsui, 2004). Voucher specimens provide verifiable and permanent records of wildlife and environmental conditions. In contrast to many forms of botanical collection where only parts of a plant are collected, faunal voucher specimens require the sacrificing of an individual animal. Understandably, that loss of an animal's life results in concerns about animal welfare and conservation (Lunney, 2012), particularly for vertebrates (there is generally far less concern voiced about the welfare of invertebrates). Thus the decision to collect an animal is not made lightly or without substantial independent permitting and review. However, increasing resistance to the collecting of specimens (e.g., Minteer *et al.*, 2014) threatens to undermine the imperative to record today's dynamic faunal conditions for future generations to reference and study.

The Australian state of Victoria's *Flora & Fauna Guarantee Act* (1988) requires that all of Victoria's native flora and fauna can survive, flourish and retain potential for evolutionary development. This legislative requirement cannot be met without a clear understanding of the taxa that make up Victoria's biota - an understanding that cannot be achieved without comprehensive specimen collections. Furthermore, the *Museums Act* (1983) states that the functions of Museum Victoria are, 'to develop and maintain the State collections of natural sciences, …[and] to promote the use of those collections for scientific research.'

In this paper, we first argue that the maintenance and scientific value of faunal collections require continued collection of voucher specimens, using vertebrate specimen collection in Victoria as a focus. Second, we present a framework with which researchers can evaluate the need for and guide the collection of vertebrate specimens.

What are voucher specimens?

Voucher specimens are verifiable and permanent records, because they preserve as much of the physical remains of an organism as possible (Gans, 1993). Traditional voucher specimens include taxidermied study skins, cleaned skeletal material, and spirit specimens (Table 1). The latter represent whole or partial animals fixed in a preservative (e.g., formalin or ethanol). Each of these preparation methods preserves different aspects of an organism, requiring multiple specimens to document as complete a record as possible.

The formal taxonomic description of every non-fossil species is based on traditional voucher specimens, and the type specimens upon which the names of species are defined must be voucher specimens. Voucher specimens are extremely valuable because they preserve the characters by which species can be distinguished. In many instances, these are very small, requiring microscopy (e.g., reptile scale counts, pre-anal and femoral pores, and subdigital lamellae), or are not present or visible on the external anatomy (e.g., skull characteristics), so a whole voucher specimen is critical to their definition.

Current methods of specimen preparation and collection retain more data than ever (Table 1) and can be used in a multitude of ways (Vuilleumier, 1998). Modern specimens are often coupled with photographs, audio recordings (e.g., frog calls), and GPS-based localities that improve the documentation of their condition and provenance. The greatest shift in modern voucher specimens has been the proliferation of genetic samples coupled with traditional whole animal vouchers. These genetic samples are collected from multiple tissue types (e.g., muscle, heart, liver), and preserved cryogenically or in a fixative that slows degradation (e.g., ethanol, RNALater). Increasingly over the last decade, these tissue samples have been accessed for uses other than just DNA, including messenger RNA (the expressed form of DNA in cells), proteins, parasites, venoms, toxins and odorant compounds (e.g., Perkins *et al.*, 1998; Nishimura *et al.*, 2012).

The value of genetic samples to museum research has led to an increasingly common perspective that non-destructive genetic samples collected directly (e.g., blood, tail tip) or indirectly (e.g., scat, hair, feathers) from the animal are adequate replacements for physical specimens (Minteer *et al.* 2014; Table 1). These non-destructive genetic samples are valuable because they can provide a larger population genetic sample size than would otherwise be prudent if collected as vouchers from a single locality. In some species, where genetic variation has been previously characterised, non-destructive genetic samples can also provide documentation of an individual's identity. However, genetic samples lack many other sources of information preserved in voucher specimens (Rocha *et al.*, 2014). Non-destructive genetic samples are typically small in size / volume, and often provide sufficient material for only limited analyses or just a single research project. Thus, they have restricted utility for documenting a species permanently. They also lack relevant RNA and other molecular information that is preserved in the tissues of entire voucher specimens. Finally, genetic samples without voucher specimens do not retain phenotypic morphological information that could be associated with genetic variation (for a practical example of why this is important, see Adams *et al.* 2014).

Victorian species' records also come in the form of photographs, videos, and audio recordings. For some species, these can be sufficient to identify currently recognised species, and they provide a low impact and efficient way to document species' occurrences. These records can preserve various aspects of an organism that otherwise are not preserved in voucher specimens (e.g., calls, behaviour). However, the value of these records is limited when taxonomy redefines species' limits, or for species that are difficult to distinguish from gross external morphology. Many small and complex characters that define species are not apparent on photographs. Images captured by remotely-triggered camera systems are often of low resolution; these enable identification of well-known species, but can be of limited value for small or similar species. In contrast, voucher specimens provide a range of data that cannot be quantified from photographs, such as colour, morphology, internal structures, diet, sex, and reproductive data.

Purely observational records, where there is no substantiated record of the species except the notes of an astute observer, reduces the long-term value of the data because questionable records are unverifiable (Rocha *et al.*, 2014). The validity of an observation as a permanent record is dependent on both the expertise of the observer and the degree to which the expertise of the observer is known by the end user. These records also lose value with changes in taxonomy where it can be impossible to assign the original identification to a currently recognised species. Observational records that are coupled with representative voucher specimens are the most valuable because they demonstrate the expertise and accuracy of the observer, and can be assigned to species even after taxonomic revision.

Why are voucher specimens so valuable?

The immense value of specimen collections for research and reference underpins our understanding of biodiversity, and these collections are critical for conservation assessments now and in the centuries that follow. Voucher specimens serve a variety of purposes, including providing the foundation for understanding taxonomy and biodiversity, and are a verifiable record of faunal conditions over time and space that can be referred to repeatedly into the future. Museum collections are used in many ways, including contributing to public health and safety by permitting an examination of the history of infectious diseases and their sources or reservoirs (e.g., Suarez and Tsutsui, 2004). Perhaps the greatest value of specimens is that they provide opportunities for future study. Here we highlight some of the more common uses of voucher specimens within Victoria's vertebrate collections.

Table 1. Types of vertebrate records, their uses and drawbacks, and the direct impact of these records on individual fauna.

Record Type	Examples	Information content / uses	Example of uses	Drawbacks	Direct impact to individual
Voucher specimen (non-DNA)	Skins, skeletons, spirit specimens	Complete record of species' morphological phenotype (internal and external) Lasting record	Taxonomy, species identification; dietary analysis, morphological adaptation and acclimation, reproductive biology, ontogenetic studies, biogeography, demographic studies (e.g., sex ratios), global change and phenotypes, isotopic analysis, disease and public health research, ecotoxicology, phenology	Removes individual from the population; time- and cost-intensive; requires specialised skills	Death
Voucher specimen (DNA)	Tissues	Complete genome of individuals, tissue-specific RNA expression, proteins, parasites and disease	Phylogenetics, species delimitation, population genetics, phylogeography, kinship, proteomics, transcriptomics, public health and disease, genotype-phenotype association studies	Removes individual from the population, time- and cost-intensive, requires specialised skills	Death
Direct DNA specimens	Ear snip; toe / tail / fin clip; blood sample	Complete genome of individual. Value greatly increased by subsamples of voucher specimens from same locality	Phylogenetics, population genetics, phylogeography, kinship, species delimitation (if coupled with vouchers from same locality)	No record of the individual's phenotype; difficult to assign to new taxa when described. Often limited in quantity allowing relatively few studies. Does not preserve RNA	Minimal
Indirect DNA specimens	Scat, hair, feather sample, shed skin, scale, skin and buccal swabs	Some genetic approaches, testing for pathogens (e.g., the amphibian chytrid fungus in frogs)	Predator dietary analysis, species identification (where species are readily distinguishable by limited DNA alone), population genetics, phylogeography	Contamination issues relating to mis-identifications. Poor quality DNA for most genetic techniques	None
Image and audio recordings	Camera traps, photographs, video, audio recordings	Captures an image or audio recording of fauna, including its colouration. Provides species record that can be evaluated by multiple people, can 'ride out' inappropriate survey weather, allows for 24 hour site surveying	Broad-scale surveys and monitoring particularly for species with large ranges, rare encounters, or in difficult to sample habitats	Not suitable to detect some species; characters required for identification may be obscured or missed. Sex, age, and other phenotypes not preserved	None
Observation	Visual or auditory observation reported by individual	Potential species record at a locality	Phenology (e.g., Bird migrations), distribution records, citizen science (e.g., iNaturalist, BowerBird, eBird)	Unverifiable record; relies on expertise of observer and knowledge of observer's expertise by end user	None

1. Taxonomy, recognition of biodiversity, and conservation

Species are the fundamental unit of biodiversity. Therefore, responding to the modern biodiversity crisis (Pimm and Raven, 2009) requires a robust taxonomic and geographic understanding of species' limits. Delineation and description of species require the definition of physical characters that can be measured or observed on specimens. For every species, a designated holotype (and usually a series of associated type specimens) provides the physical evidence that justifies the application of a specific name. Any changes in taxonomy require comparison to relevant type specimens preserved in museum collections. Thus, taxonomy without specimens does not exist.

Properly prepared and curated voucher specimens last indefinitely, and thus provide a unique historical record of the fauna of a given area (Gans, 1993). Taxonomic revisions, even those using modern molecular techniques, that result in the 'splitting' of a nominal species into two or more taxa may not only require the collection of new specimens, but also the re-examination of existing specimens in order to determine the identity of taxa that occur (or once occurred) in an area. For example, morphological and genetic analyses demonstrated that the lizard *Rhynchoedura ornata* consists of five species (Pepper *et al.*, 2011); however, specimens from Museum Victoria were not included in this analysis, and assignation of Victorian lizards previously referred to as *R. ornata* will necessitate examination of existing preserved specimens from Victoria, and perhaps collection of further specimens (P. Robertson pers. comm.). The revision of the dasyurid marsupial *Antechinus stuartii* revealed that southern populations were a distinct species, *Antechinus agilis,* requiring re-examination of voucher specimens from across the range of the two species to determine distributional limits (Dickman *et al.*, 1998). Descriptions of new species of Australian mammals demonstrate the need for effective collecting (e.g., Kemper *et al.*, 2011; Baker *et al.*, 2012). Similarly, taxonomic revisions in fishes are common; for example, *Galaxias olidus* has recently been divided into 15 species (Raadik, 2011; Adams *et al.* 2014), necessitating a re-examination of museum specimens from across Victoria and south-eastern Australia to determine their identification and distribution. In addition to providing the basis for naming and describing species, voucher specimens are necessary for the identification of morphologically similar taxa, such as the freshwater fish *Craterocephalus stercusmuscarum fulvus* and *Craterocephalus fluviatilis* (Ivantsoff and Crowley, 1996).

The conservation of species is increasingly concerned with preserving evolutionary potential (Moritz, 2002), including local adaptation and variation within species, which are population-level phenomena, and dynamic over time. Subspecific taxa and / or local variation are the drivers of evolution (Schodde and Mason, 1999); only a comprehensive series of specimens from across the geographic range of a species allows an appreciation of variation within the species - an understanding that is essential to the conservation of the diversity contained within that species, and hence its evolutionary potential. In the words of Joseph (2011), collections are 'repositories of the evidence for and results of evolution' (p. i).

2. Ecology and the environment

Museum collections that include a variety of preparations, life stages, geographic locations, and time series provide unique opportunities to explore species' ecologies and the status of their environment (Pyke and Ehrlich, 2010). Specimens form a primary resource for studying topics as diverse as reproduction, morphology, skeletochronology, diet, habitat use and preferences, and geographic distribution and variation (e.g., Shine, 1980a; 1980b; 1981; 1989; 1991). For example, fish otoliths provide researchers with information on growth rates and aging, general biology, habitat occupancy, recruitment, movement and migration, as well as the diet of other species (Campana, 2005; Furlani *et al.*, 2007). This may be particularly important for threatened, endangered and declining species, for which these data are necessary to develop effective conservation plans (e.g., Clemann *et al.*, 2004). Specimen collection that targets communities, such as marine surveys or general collecting trips, can provide additional information, not only on individual species present at a given location, but also give an indication of community composition (Grinnell, 1910).

Understanding species' distributions requires vouchers for reliable and verifiable identification of the species, in addition to locality data. The presence of a vouchered record from a region helps to substantiate less verifiable records (such as catch-and-release records, sightings, acoustic records, nests, burrows and tracks) from that region. Significant records, such as range extensions or first records of a species from a jurisdiction (e.g., Raadik and Harrington, 1996; Clemann *et al.*, 2007; Gillespie and Chang-Kum; 2011; Kemper *et al.*, 2011), are best substantiated with a voucher specimen to eliminate ambiguity in identification. Conversely, a lack of vouchers can render published results unverifiable (Wheeler, 2003), and supposed records of some significance that are not substantiated with sufficient evidence (e.g., Urlus and Marr, 2011) can be open to criticism (e.g., Clemann and Gillespie, 2012). Distributional data (preferably substantiated by voucher specimens), when combined with other spatially- and temporally-explicit data (e.g., temperature, precipitation, land use) can be used to predict the presence of species in areas that have not been sampled (species distributional modelling; e.g., Kearney and Porter, 2004), or project likely distributions into the future (e.g., Kearney *et al.*, 2008).

In a dynamic world, collections have both a temporal and spatial element (Gans, 1993; Feeley and Silman, 2011); changes in geographic distribution, size class representation, disease status over time (e.g., Cheng *et al.*, 2011; Richards-Hrdlicka, 2012) and even physical changes in species over time (Gardner *et al.*, 2008; Eastman *et al.*, 2012) necessitate specimen time-series of varying duration. Newly emerging techniques can be applied across historical samples to investigate temporal changes in species' distribution (see Smith *et al.*, 2013). Natural systems are dynamic, and processes such as climate change mean that the value of specimens from a particular region is not static; the faunal situation at any point in time provides a data point for comparison with conditions before and after that point in time. Shifts in distribution, age structure, timing of breeding and migration (Green and Scharlemann, 2003), and trophic level (Becker and Beissinger, 2006) can all be assessed using long-term collections of specimens. Specimen series also provide evidence of movement of taxa due to seasonal changes, such as the transition or replacement of migratory species across different seasons.

3. Future opportunities and value

Voucher specimens provide the most complete record of an organism and the greatest opportunity for repeated and future biological study, especially for unexpected uses (Rocha *et al.*, 2014). Failure to collect specimens can render some studies unreliable because the identity of the study species cannot be verified (Krell and Wheeler, 2014). The unexpected value of museum specimens for future research is best exemplified by the environmental disaster created by the pesticide DDT (dichlorodiphenyltrichloroethane) in the middle of the 20th century. Comparison of eggshells in museum collections from before and after 1946 (the onset of DDT use) demonstrated a dramatic decrease in eggshell mass (Ratcliffe, 1967; Peakall and Walker, 1994). This examination of museum specimens, collected for entirely different purposes, was the first indication of the devastating impacts of DDT on wildlife, and ultimately led to legislative control of DDT use, and the subsequent recovery of wildlife.

In 1857, when Wilhelm Blandowski, the first state zoologist of Victoria, set out to chart the natural history of the arid interior near the confluence of the Murray and Darling Rivers, he presumably had no conception of a looming biodiversity crisis and could not know that 11 of the mammal species he collected would be extinct or extirpated from the region within 100 years (Menkhorst, 2009). Blandowski's specimens, preserved in the collections of Museum Victoria, provide a critical record of species' prior to their extinction or decline. For example, the Lesser Stick-nest Rat *Leporillus apicalis* was extinct by the 1930s, but on Blandowski's expedition it was one of the most common species collected, with 27 individuals still in the collection of Museum Victoria. These specimens provide a verifiable record that *L. apicalis* was a common component of Victoria's semi-arid ecosystem prior to its extinction. Similarly, there are Victorian species that have not been verifiably recorded in the state for more than 40 years, such as the Eastern Quoll *Dasyurus viverrinus*, the Grassland Earless Dragon *Tympanocryptis pinguicolla* and the Southern Barred Frog *Mixophyes balbus*; it is plausible that these species no longer occur in Victoria, and specimens of these species held by Museum Victoria may represent the only material evidence from their former occurrences in the State.

At the time of Blandowski's expedition, the discovery of DNA was about 100 years into the future, and, unknown to Blandowski, the skins and skeletons he collected also preserved fragments of DNA that can be extracted and analysed today (Rowe *et al.*, 2011; Bi *et al.*, 2013). Stable isotope analysis, in which slight changes in the atomic mass of elements preserved in voucher specimens can be informative about the diet, environment and movements of an organism, is another emerging field that highlights the unexpected information that can be obtained from voucher specimens with new technology (Kelly, 2000; Newsome *et al.*, 2007; Inger and Bearhop, 2008; Hobson, 2011). The value of voucher specimens and the depth of information that they preserve will only increase as new technologies emerge.

Impact of voucher specimen collection on wild populations

The impact on wild populations of scientific collecting of specimens is usually infinitesimally small, especially compared with other causes of mortality, including predation, disease, weather events, hunting, collision (e.g., road kill), and habitat loss or alteration (Erickson *et al.*, 2005; Skerratt *et al.*, 2007; Collins and Kays, 2011; Rocha *et al.*, 2014). For example, the entire vertebrate specimen collection of Museum Victoria, compiled over more than 150 years from localities all over the world, totals less than 640,000 specimens. Of these, fewer than 200,000 individuals have been collected within Victoria (Figure 1). These amount to fewer than one vertebrate specimen (fish, amphibian, reptile, bird or mammal) per square kilometre of Victoria over the last 150 years. Of course, sampling is not evenly distributed across the state - the greatest concentration of collecting has occurred in the Melbourne metropolitan area (Figure 1). In many cases, specimens were collected from localities where subsequent urban development has eradicated the habitat and the populations of fauna that occupied it. Key elements of the biology and the ecology of those populations are now preserved as voucher specimens at Museum Victoria.

Roads present a major source of mortality for wild populations of native vertebrates. An estimated 377,000 to 1,500,000 vertebrates are killed along Tasmanian roads each year (Hobday and Minstrell, 2008). Other studies have estimated single species rates of road kill ranging from 2.1 to 78.8 individuals km^{-1} y^{-1} (Freeman, 2010 and references therein; Quintero-Ángel *et al.*, 2012). Vehicles kill an estimated five million Australian reptiles and frogs annually (Ehmann and Cogger, 1985).

Exotic predators such as foxes and feral and domestic cats also are a cause of significant mortality for small vertebrates in Australia (Read and Bowen, 2001; Spencer and Thompson, 2005). Studies looking at predation by domestic cats have suggested upwards of 85 million vertebrates were killed across Great Britain within a 5-month period (Woods *et al.*, 2003), between 39 to 730 million animals are killed annually within the state of Wisconsin in the USA (Coleman and Temple, 1996), and suburban cats in Canberra kill between 10.2 and 23.3 animals per cat annually (Barratt 1998). Similarly, in freshwater environments, salmonids (trout) and other introduced predatory fish species prey extensively on smaller native fish (McDowall, 2006; Raadik, 2011; Harris, 2013) and frog species (Gillespie, 2001), eliminating populations and driving some species close to extinction.

Hunting and fishing, both of which are regulated for sustainability in Victoria under the authority of the *Wildlife Act* (1975) and *Fisheries Act* (1995), are also significant sources of animal mortality within Victoria. In 2012, duck and quail hunters are estimated to have killed 638,000 native birds (Moloney and Turnbull, 2012). Likewise, commercial and sport fishing around the world results in many times as many fish

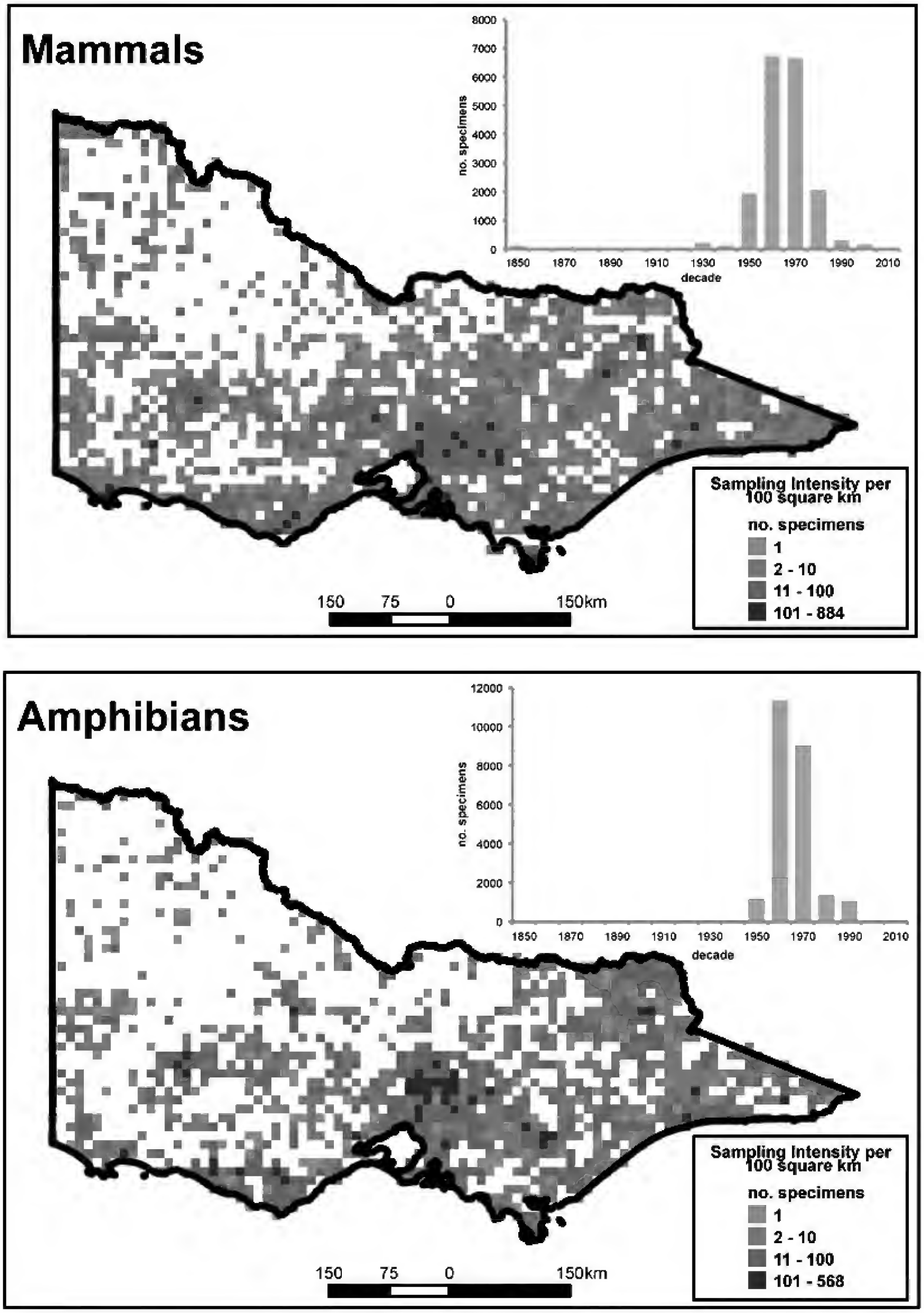
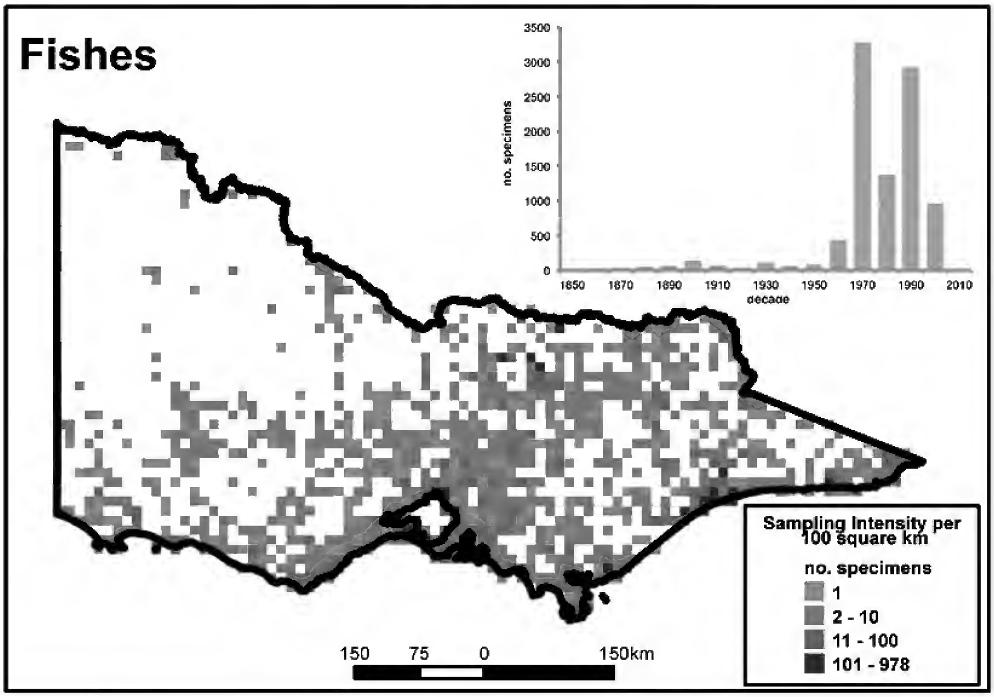
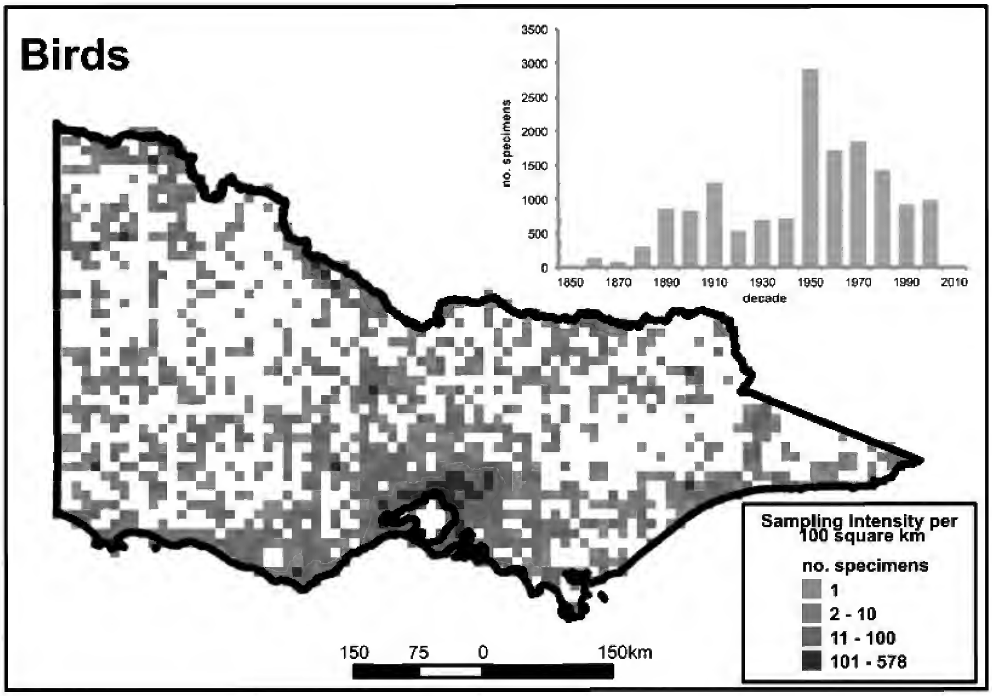
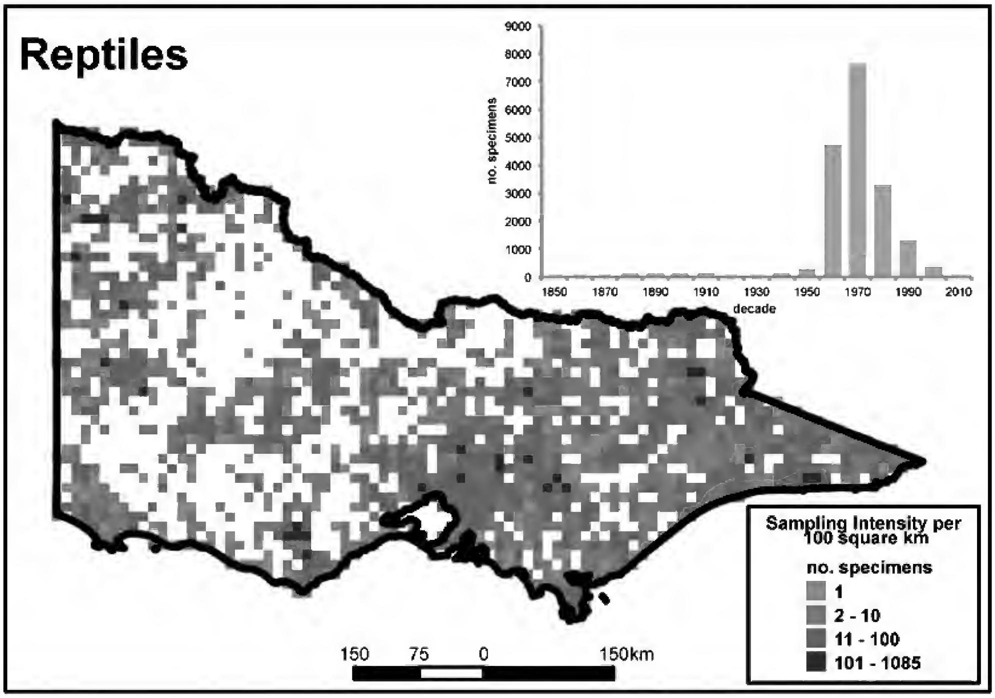
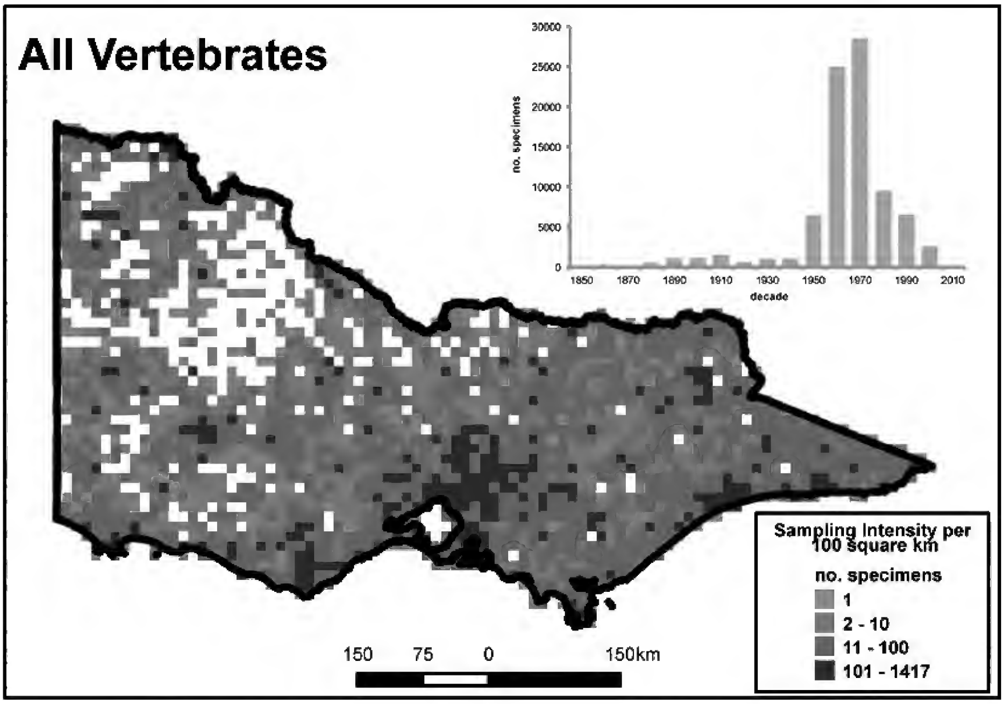


Figure 1. Geographic distribution of Museum Victoria's non-marine Victorian vertebrate specimens. Each pixel represents the number of specimens collected within a 100 km^2 grid (10 x 10 km square) from the earliest georeferenced specimen (collected in 1858) to 2012, spanning 154 years. Yellow, green, light blue, and dark blue pixels represent single (1), low (2 – 10), moderate (11 – 100), and high (> 100) numbers of specimens, respectively. White pixels represent areas with no specimens. Histograms represent the number of specimens by decade.


Fishes
no. specimens
3500
3000
2500
2000
1500
1000
500
0
1850 1870 1890 1910 1930 1950 1970 1990 2010
decade
Sampling Intensity per 100 square km
no. specimens
1
2 - 10
11 - 100
101 - 978
150 75 0 150km


Birds
no. specimens
3500
3000
2500
2000
1500
1000
500
0
1850 1870 1890 1910 1930 1950 1970 1990 2010
decade
Sampling Intensity per 100 square km
no. specimens
1
2 - 10
11 - 100
101 - 578
150 75 0 150km


Reptiles
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
no. specimens
1850
1870
1890
1910
1930
1950
1970
1990
2010
decade
Sampling Intensity per 100 square km
no. specimens
1
2 - 10
11 - 100
101 - 1085
150
75
0
150km


All Vertebrates
30000
25000
20000
15000
10000
5000
0
no. specimens
1850
1870
1890
1910
1930
1950
1970
1990
2010
decade
Sampling Intensity per 100 square km
no. specimens
1
2 - 10
11 - 100
101 - 1417
150
75
0
150km

mortalities each year than all the fish ever collected for scientific collections (Pauly *et al.*, 1998; Allan *et al.*, 2005). In Victoria alone, there are approximately 720,000 fishers in the Victorian recreational fishing sector, 290,000 of whom annually target freshwater species (VAGO, 2013), including native species.

Loss of habitat is often the single greatest immediate threat to fauna populations (e.g., Wilcove *et al.*, 1998). Voucher specimens can be the primary source of information on populations prior to habitat loss (or even the only source, in cases where species have been entirely extirpated, such as is likely for the lizard *T. pinguicolla* around Melbourne). Healthy habitats often harbour locally abundant populations of otherwise rare taxa that are resilient to targeted collecting, for as long as the habitat is secured. For example, although restricted to a few alpine plateaux in south-eastern Australia, the nationally threatened Alpine She-oak Skink *Cyclodomorphus praealtus* and Guthega Skink *Liopholis guthega* can be locally abundant where they occur (N. Clemann unpublished data), and judicious collecting does not pose a threat to these populations. A legislative preoccupation with protecting individuals of Australian animal species, instead of habitat and populations, has been strongly criticised (Rawlinson 1980; Ehmann and Cogger, 1985). Judicious collection of specimens of these individuals for research has been shown to be a negligible component of overall mortality from both natural and human-induced sources (Ehmann and Cogger, 1985). Furthermore, once an organism is included on a threatened species list, resistance to collecting is often greatly magnified (Gans, 1993), despite an often urgent need to gather information to promote the persistence of these species. There is concern about the impact of collecting on small and vulnerable populations (Minteer *et al.* 2014), although it is likely that, if judicious collecting resulted in the total loss of a population or species, that population or species had little chance of persisting for much longer whether or not collecting occurred (Rocha *et al.* 2014), and there may be immense value in securing specimens prior to the final loss.

Considered collecting: a framework to guide the collection of voucher specimens

Despite their value and importance, careful consideration should be made when deciding whether or not to collect voucher specimens and, if the decision is made to collect, how to do so. In this section, we propose a framework to guide the decision-making process for the collection of vertebrate specimens within Victoria and elsewhere.

Decisions regarding the collection of vertebrate voucher specimens should focus on four main issues (Fig. 2): 1) are there knowledge gaps for the target species?; 2) do sufficient voucher specimens exist to address knowledge gaps?; 3) will collection have detrimental impacts on the targeted population?; and 4) can the target species be collected ethically? These considerations should include both species- and population-specific aspects, rather than individual-based criteria.

As discussed above, there are many reasons to collect voucher specimens. For example, are there taxonomic, phenotypic or genetic questions that cannot be answered with existing specimens? If there are such questions, which populations and how many individuals would be needed to address the current research objectives? If there is a demonstrated need for voucher specimens additional to those currently available, the collection may be warranted. In this case, targeted collection from populations that could provide unique insight should be prioritised. Where species are known to be in decline, or where habitat that is known or likely to be occupied by a threatened species will be destroyed, the need to collect representative specimens is urgent. For example, expansion of Melbourne's urban areas is resulting in the removal of grassland habitat occupied by the federally endangered Striped Legless Lizard *Delma impar.* Before this habitat is cleared it is imperative that representative specimens are collected from this area so that we have some record of what has been lost. Habitat currently earmarked for clearing includes areas where no collection had occurred, but samples were required for molecular analyses aimed at defining Evolutionarily Significant Units in this species (Maldonado *et al.*, 2012). Consequently, there is an urgent need to collect this material prior to the loss of these habitats and populations. Collection of specimens during a decline can even help to highlight the processes driving losses (e.g., Green, 2008), with the potential to aid in population or species recovery.

Deciding from which populations to sample and how many vouchers to collect should be firstly based on ecological and population considerations, and will likely vary between species. For example, both the global and local distribution of the species should set the context for targeting populations for collecting. Geographic gaps, populations at the species' range limit, or isolated populations may be particularly informative. Alternatively, repeated sampling at known localities can inform change or stasis of a species through time.

Secondly, local abundance should be considered – is the species widely distributed and generally uncommon, but locally abundant in the focal population? In this case, targeted collection within the locally abundant population could be particularly informative with minimal impact on the species as a whole. At times there is considerable resistance to collecting specimens, especially threatened species, from certain land tenures, such as the parks system or land covenanted for conservation purposes (Gans, 1993). However, we believe that more biologically relevant criteria than land tenure alone should form the basis for prioritising areas for collection. Being prevented from collecting in reserved areas where a species may be most abundant, and therefore being forced to collect in non-reserved areas where the species is less common, can result in strain on non-reserved populations that would not be evident on those in reserves.

Thirdly, the reproductive biology of the species should guide numbers and timing of collection. Different consideration should be made for species that are long-lived with slow reproductive rates, versus those that are short-lived with high reproductive rates. The reproductive stage of the population should also be considered. Individuals considered less valuable (according to biological criteria) than other individuals to a vulnerable wild population may be preferentially chosen for collection; for example, Clemann and Beardsell (1999)

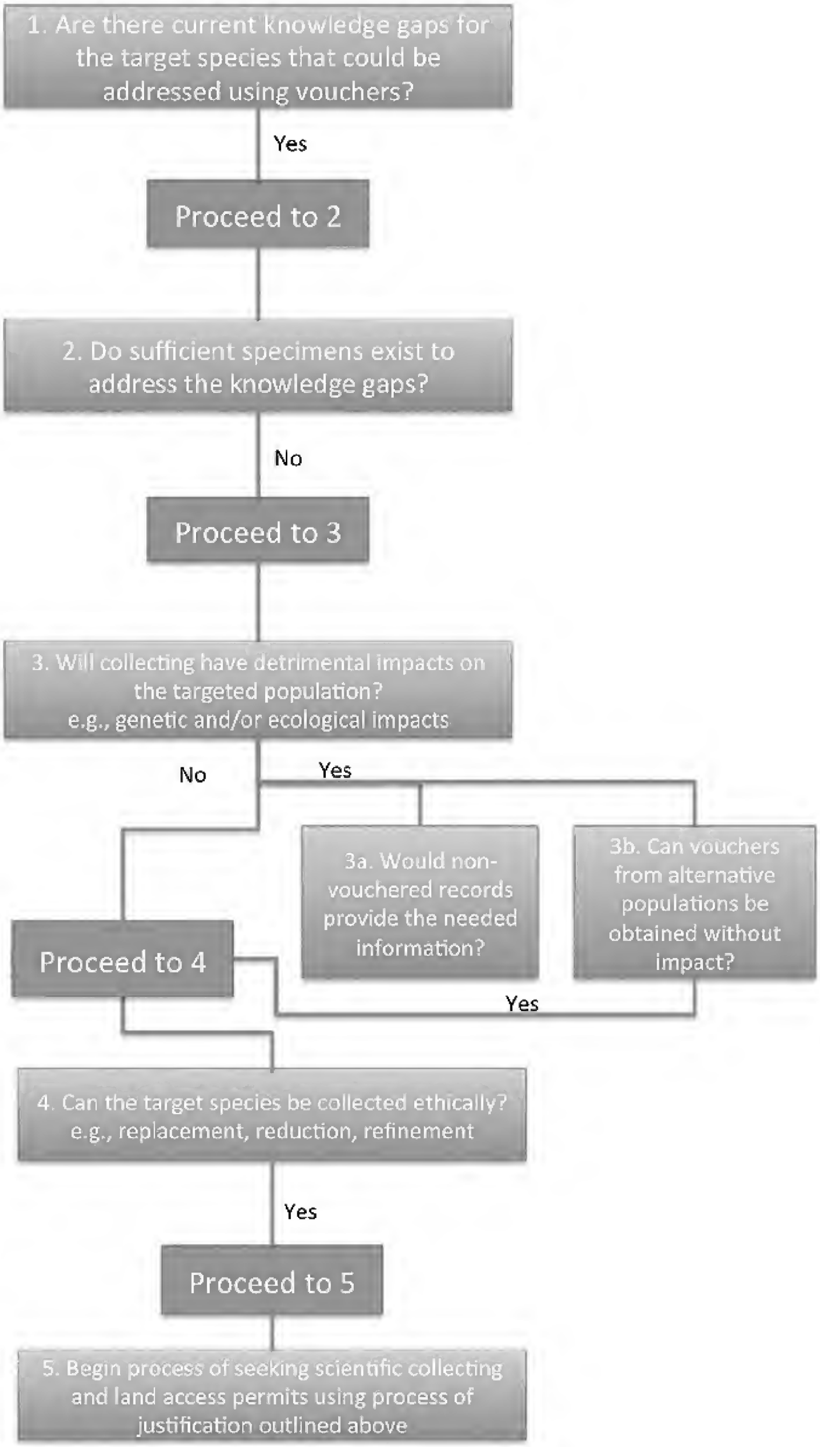


Figure 2. Decision process when considering collecting voucher specimens. Questions to consider are given in blue, with responses to each question given in black. Directions on how to proceed through the process are given in green. Further details and examples are provided in the text

captured a gravid female of the threatened Swamp Skink *Lissolepis coventryi*, and chose to release the female and all but one of the resulting offspring – the remaining neonate forming the voucher specimen to confirm this significant record. Similarly, excess bachelor males could be sampled for a species where few dominant males control territories and access to reproductive females, as in fur seals (Kirkwood and Goldsworthy, 2013). However, for some purposes one specific sex is needed, such as taxonomic studies of some bats where penis morphology is diagnostic (Reardon *et al*. 2014.).

Fourthly, researchers should identify if there are any existing local impacts on the focal population and consider how collecting will compare to those impacts. All populations are regulated by mortality rates, natural and human-induced; in almost all situations where judicious collecting of specimens occur, such collection represents a negligible fraction of mortality rates. If current threats outweigh the collection of limited numbers of vouchers, and collection could provide valuable information about the current status of the population, then collection of vouchers may be warranted. In addition, population-specific factors, such as local abundance, should guide numbers of vouchers (although collected numbers should not exceed the minimum to achieve all objectives).

Ethical considerations for the collection of vouchers are an important part of the process. Procedures for the collection of fauna in the wild are guided by established standards and upheld by animal ethics committees. Limits on the numbers of specimens that may be collected are regulated through federal and state agencies, under advice from scientists and wildlife managers. Collection of specimens should be judicious, with only the numbers needed collected. But, equally, it is folly to 'under' collect, as the cost of returning to the field to collect more specimens may be high; and in worst-case scenarios for declining species, future collection may not be possible due to scarcity or a total loss of a taxon from an area. Finally, the proper preparation and curation of specimens, along with accompanying data, should be mandatory to maximise the value of the specimen to future researchers.

Increasing resistance to returning research animals to the wild (e.g., Clemann, 2013) can create another source of specimens when research animals are retained at the conclusion of a project. Specimens collected for research purposes should be (and often are) required by permit regulations to be deposited in curated museums. These specimens should be accompanied by at least a minimum amount of collection information (e.g., collector name and affiliation, date, and accurate location details) in order to facilitate future research.

Conclusion

We acknowledge the role that advances in technology and increasing animal rights and welfare concerns play in the protection of individuals and populations of wildlife. However, judicious collecting of faunal specimens has underpinned most avenues of zoological investigation, and we argue that targeted collection of vertebrate voucher specimens will continue to provide a crucial component of our understanding of the natural world. Now and into the future, collections that are refreshed and expanded will provide the basis for advances in understanding of native animal zoology and conservation management.

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